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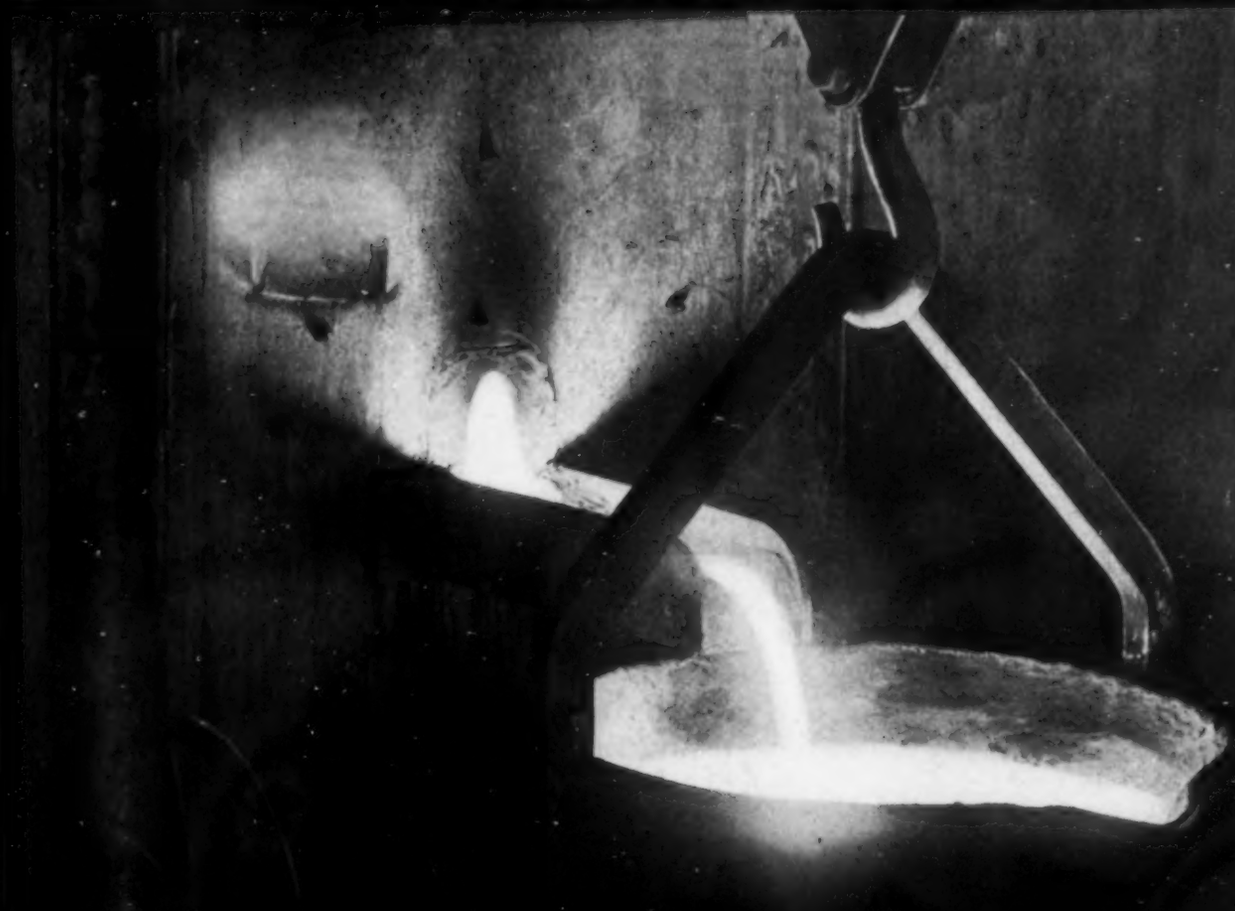

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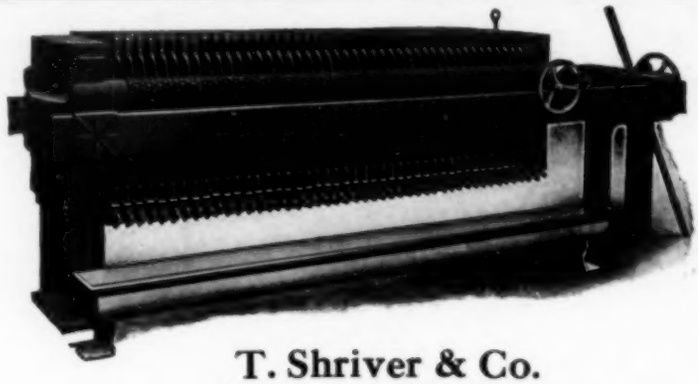

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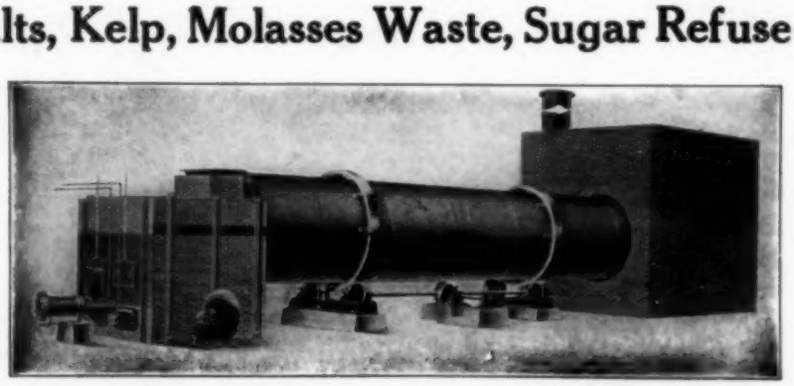

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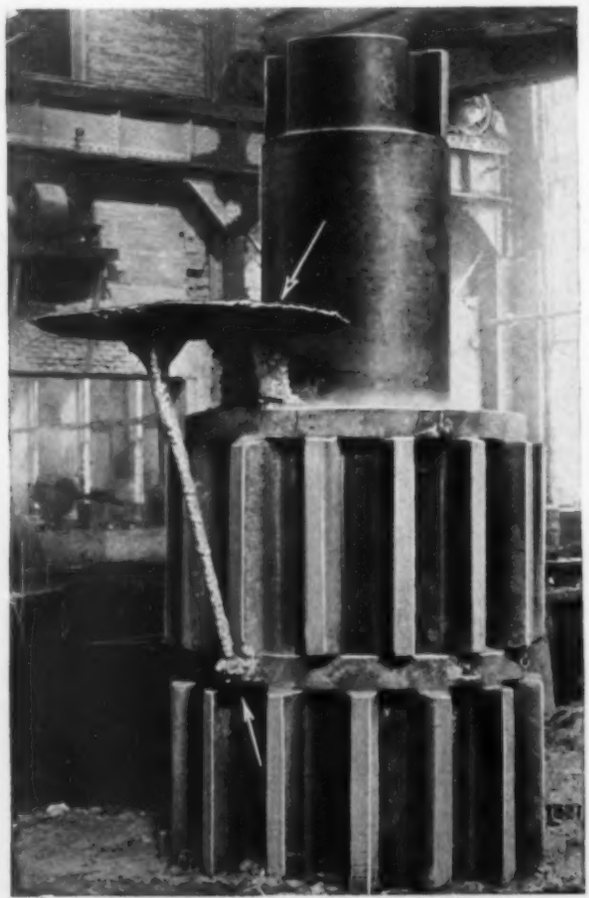

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Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

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The Power Famine at Niagara Falls and National Industrial Preparedness

Elsewhere in this issue (on pages 239 and 259 respectively) full reports will be found of two unusually interesting meetings held last month by the two liveliest and most aggressive local sections of the American Electrochemical Society, the Niagara Falls section and the New York section. At Niagara, under the chairmanship of Mr. F. A. Lidbury, the subject of discussion was the power famine at Niagara which has been growing worse from year to year and is now most serious in its threatening consequences. At New York City, under the chairmanship of Dr. C. G. Fink, the discussion related to "electrochemical war supplies" with special reference to national preparedness. Strange it may seem but it is true that the subjects of the two meetings are intimately related to each other. The discussions at both meetings deserve the most careful attention of everyone. We can touch at this place only on a few salient points of many which were brought out.

The fundamental trouble with waterpower legislation in this country in the past has been that those responsible for it have been too exclusively obsessed with one-sided aesthetic scruples and with the fear of the ghost of a waterpower trust and have never risen to a full realization of what developed waterpower means or would mean to the consumer and to the whole life of the nation. It is not generally and not clearly enough realized that the price this country is paying continually for the preservation of the spectacle of Niagara Falls amounts to something like a million tons of coal a week. Using another unit for expressing the economic equivalence, Mr. F. J. Tone brings the matter even more strikingly home to the public: if the Niagara power was devoted to the production of nitrogen fertilizer it would produce sufficient nitrogen for 3,000,000 bushels of wheat a day. Let it be clearly understood that the failure to develop available waterpowers means a continuous irretrievable economic loss of startling dimensions. The only real loser is the nation.

Mr. Tone's nitrate example is particularly appropriate because for the industrial self-containedness and for the very independence of a nation a sufficient nitrate supply is a fundamental prerequisite in peace and in war, for fertilizers and for explosives. The fact is that in the past this country has relied wholly on nitrate importations from Chile. Mr. W. S. Landis is right in pointing out that Germany has been able in a single year to make itself independent of importations by rapidly developing electrochemical nitrate processes on a marvelous scale, and he is also right in saying that with respect to the production of cyanamid and subsequent transformation into ammonia and nitric acid "there are

no problems the solution of which is not now resident in the United States, and therefore we feel that this country is to-day in as good, if not in a better position to supply its own nitric acid for ammunition purposes than Germany was at the beginning of the war." But to state the facts in the case completely, it must be added that the only large American cyanamid plant is not in the United States, but on the Canadian side of Niagara, and that the cyanamid industry is one of those which were forced by the power famine on the United States side to go out of the country. When it comes to figure the cost of undeveloped power and the economic loss of the country, let the expatriation of industries of fundamental importance be not forgotten.

We cannot expect too much from our law makers, but we expect that something be done. Mr. Albert H. Hooker's proposal is excellent. Well over 1,000,000 hp. more could now be developed at Niagara and not a bit of injury would be done to the scenic grandeur of the cataract if a little engineering skill were used in placing the proper brakes and deflectors. Let this be done with the provision that for every 100,000 hp. newly developed, say, 10,000 hp. be devoted to the fixation of atmospheric nitrogen; the more varied the methods the better. In any sensible program of preparedness chemical preparedness and chemical self-containedness must be fundamental and nitrate production from the air must play a big part; the crux of the matter is more Niagara power. The American electrochemists may be safely relied upon to do the rest.

Metal Prices and Wages

The wage earner in the mining and metallurgical industries is sharing with the operator in the profits flowing from the increased prices of the base metals. The daily press cites numerous instances of wage increase and of sliding wage scales based on metal prices, particularly in the copper, zinc and steel industries. Lead has not yet shared in the general advance in as great measure as the other metals.

Utah mining and smelting companies generally have granted advances, the Utah Copper Co. alone being reported to have increased its pay-roll by about $50,000 per month. Kansas and Oklahoma zinc smelters and Joplin mining companies also have granted substantial increases. Colorado and Eastern iron and steel workers have been recognized, and wherever unusual profits are being made the worker is sharing in some degree. Conditions are in marked contrast with those of August, 1914, when production was curtailed and workmen were offered employment on half time.

The attitude of the operators is wise as well as just. The workman is entitled to a share in the enhanced value of his product. This is no time to incur his enmity or ill will, for he is a factor that cannot be ignored. We like to believe that the operators recognize the justice of these wage increases, and that they are not merely placating the men through fear of dissension or strikes that would mean cessation of operations and consequent loss. And signs are not lacking that an intelligent view of coöperation is surely replacing the sentiment of antagonism that prevailed all too widely in the ranks of employer and employee only a few years ago. The millennium is not yet at hand, but we are in a fair way to avoid repetitions of the distressing state of affairs that recently prevailed in Arizona for four months, and which has been settled on an amicable basis. A point to be kept in mind by both sides is the necessity of being equally considerate and tolerant when prosperity is not as marked as it is to-day.

A Most Remarkable Steel Situation

If the situation now obtaining in the steel market had been portrayed a year ago the sketch would have been considered fantastically fanciful. The reality is difficult to grasp. It seems impossible. The future of a market is a resolution of the forces, but in this instance no resolution seems reasonable; it looks as though it would have to be in the fourth dimension!

The steel industry, the industry of making soft steel by the Bessemer or open-hearth process, is not very old. The art passed its semi-centennial several years ago, but it was not until about a quarter century ago that the manufacture of puddled iron in the United States ceased to increase. Thus the history of the steel market is not so long but that it can be scrutinized for possible parallels. None can be found. Soft steel became the dominant wrought ferrous product during a period of industrial depression, and at its close there was a "boom," prices skyrocketing in the latter half of 1899, but the boom was short lived, and the total turnover at high prices was small from a tonnage standpoint. The next upward movement, culminating in 1902, found finished steel products under such control, a control that proved quite temporary, that they advanced unduly with respect to material in its cruder stages. Since 1902 the steel market has attained three high points, in 1907, 1909 and 1912. Of these the highest was that of 1907. At the end of 1915 the average price of finished steel products was level with the high point of 1907, $4 a ton above the high point of 1909 and $6 a ton above the high point of 1912.

It seems to be a fair statement, therefore, that at the end of 1915 the steel market was on the verge of passing beyond bounds. The period 1905-6-7 represented the greatest period of sustained and heavy demand in the history of the steel industry, and to produce higher prices than then reached would certainly require altogether exceptional and extraordinary conditions. Since the first of this year the steel market has advanced an average of fully $7 a ton, being by that length virtually out of bounds, and the going is still strong. The curve of prices is concave to the blue sky. In bars, plates and shapes, for instance, the nine advances that occurred in the first ten months of 1915 were of $1 a ton each. Then came advances of $2 a ton each, and the latest advance, made about Feb. 18, was $5 a ton. It would be instructive if the formula for the graph could be written, dx being first of the order of $1, then of the order of $2 and then of the order of $5.

The manner of doing business in steel is likewise

without precedent. Hitherto as prices advanced the steel mills would cover their customers farther and farther ahead, so that the advance in prices realized upon shipments would be quite gradual, and buyers would be well protected for the future. In this movement the mills began to curtail the making of contracts after prices had reached a moderate level, and of late they have been disposed to accept little but specific orders. The following of such a policy has tempted buyers to make up dummy specifications, which parade as specific orders, buyers knowing that the mill cannot ship for months and that opportunity will therefore be afforded to change the specification when the real wants are clearly seen. Thus the tonnage of so-called "specifications" on mill books is not as close an index as usual to what the mills will actually be called upon to deliver.

From the viewpoint from which the steel market has been regarded in the past the present situation would be impossible, and the future likewise impossible. One usually judges the future in human affairs by mapping out the possible courses of events and selecting the most probable, as the railway engineer selects the most feasible course for his proposed road. When he finds no possible course, however, he loses his job. There is no reasonable course for the steel market now to follow. Prices are already above the traditionally "safe" level, yet show a greater advancing tendency than ever. That might be held to suggest a break in the market in the near future, but a break seems to be as improbable as anything.

It is a question, however, whether there has been any really conclusive test in the past as to the ability or willingness of steel buyers to pay one price or another. To an extent the matter has hinged upon what the buyers have been able to obtain for their product, for it is rarely indeed that the ultimate consumer buys steel from a mill. As a rule steel markets have been made or broken not by the ability of the buyer to pay, but by what he expected of the future, whether prices were likely to advance or decline. His ability has not been seriously tested.

In any event, however, the "buyer of steel" is not a homogeneous quantity. One buys steel to make watch springs, another to build a bridge. There are all gradations. With sufficient detailed knowledge the buyers could be classified, the aggregation analyzed, and the groups arranged in the order in which high prices would curtail the expression, in actual orders, of their requirements or desires. If the desire to have steel represents neither more nor less than the quantity of steel that can be produced, and price exercises no deterrent influence, the production will be bought. If the desire exceeds the supply, the price can be a deterrent, as to various classes of steel, to the extent of this excess, and still leave purchases equal to the possible supply. If at any moment the deterrent is less than this excess, relief is found in price advances.

The extent to which high prices may be a deterrent to steel purchases may be overrated if the average experience of the past be taken as a guide, for the proportions in which steel has been bought of late are quite different from the proportions of the past. There has been a much smaller proportion of structural material and a much larger proportion of steel for automobiles and most other classes of material. If all the steel now being shipped could be followed to its ultimate destination, where it is to perform its actual service, the value in the case of a great percentage would be found to be a large multiple of the price received by the mill, whether that price were a cent and a half a pound or three cents a pound. In ordinary times it does not follow that the price would not be an important consideration, the buyer perhaps concluding at times it would be better to wait. The times now, however, are so disorganized that the buyer has no idea what is coming. Some buyers would not buy now even at low prices; others may care nothing for price.

If little is known as to the prospective willingness of domestic buyers to pay high prices for a large tonnage of steel—for at present the high prices are being paid for but a small tonnage of the steel shipped, owing to the filling of old orders—still less is known as to the export demand. It is currently observed that prices bid for export steel are higher than the regular prices asked in the domestic market, but the mills have been so busy arranging their orders that they have negotiated on little of the export inquiry. In good times prior to the war the great iron and steel exporting countries, Germany, England, Belgium, France and the United States, have furnished about 10,000,000 tons a year to the non-producing countries. At the present time such exports are at a rate probably somewhat under 4,000,000 tons, a trifle more than one-half being furnished by England. Obviously there is room for a large increase in our export trade, as England can scarcely increase her exports, provided the price will be paid. Imagine a conical shaped vessel containing water, with an outlet at the bottom. How much water must escape to reduce the pressure one-half? No answer. Is the cone upright or inverted? Thus with the pressure for steel for export, which causes high bid prices. One does not know how much tonnage would be sold before the bid prices would be greatly reduced.

In all this confusion one thing seems reasonably certain. When the turn comes, whether it be relatively near at hand or far distant, steel prices will not drop with the dull disheartening apathy that has characterized such declines in the past. Wants that were not expressed when prices were higher will be found expressed in orders as values decline; the buying cannot come to a sudden standstill.

The common view in the steel trade has been that the heavy demand for steel will last during the war, and even the sharper advances in prices now occurring have not served to convince the majority that the break in steel prices is likely to come sooner. The observation, of course, presupposes that the war will not be continued until complete exhaustion overtakes the belligerents, for in that case their purchases of American products would have ceased, and with it a part at least of our general industrial prosperity would end.

Readers' Views and Comments

The Chemist on the Board

To the Editor of Metallurgical & Chemical Engineering:

SIR:—Chemists are just like other men, and when they grow rich they are likely to become vain and cocky. Not all of them by any means; some are of such exquisite mental balance and are so wholesome of disposition that the more wealth and power they achieve the better it is for everybody all around. And yet very few of us are proof against the danger that accompanies the accession of wealth, or against the need of a camel ride, or against the vain belief that, so mounted, we can easily make the grand tour through the needle's eye without so much as losing any skin or compressing our camel. We know that others would have trouble and we even have concern lest they fail, but it is not so with us. We have just the balance, just the quality of poise, of savoir faire, of grace and general sensibleness to make it especially desirable that we be rich. This is our great illusion.

We say this because we believe it to be true, and more especially to take the sting out of what we are about to say. Observe, please, chemists are like other men and other men are like chemists. If they grow rich they are likely to suffer in character and in modesty. As soon as anybody has made his pile he may need to be treated with caution lest he flare up and lose his head and strut about and grow angry and demand more reverence and respect and admiration and obedience than his qualities warrant. The longer the credit balance the shorter the temper as a rule, and its operation can only be overcome by a well-oiled and easy-running condition of that part of a man's internal equipment that functions as generosity. By this we mean the larger generosity whereby one understands not only what another thinks but how he feels, and has the sympathy to avoid giving unnecessary pain. This quality is one wholly separate and apart from executive ability and good business sense.

Now if you want a competent board of directors to guide the affairs of an industrial undertaking, you must select men of experience and achievement in affairs and such men are likely to be rich. If they are, there is the danger that at least some of them may be crippled by rich man's vanity. You may sit on a board with such a man for years and not know he is suffering from this malady, and again, under some unexpected provocation it may crop out at any time in the form of a broad, yellow streak, to your amazement and distress.

In any concern engaged in the production of goods by means of chemical processes, there should be a chemist on the board for advice and to avoid mistakes. This for the same reason that there is a lawyer, either duly elected or present as general counsel, in like manner to avoid mistakes. It was intimated in the last issue of this journal that business men and especially bankers do not know chemists as such, and that few of them know the difference between a good one and a bad one, or how to tell them apart. The bad chemist has the advantage over the good one with men of business because he can promise so much more. There should be chemists on the boards of many corporations that are now even boastful that they haven't a single "theorist" in their whole establishment, if they are to avoid unnecessary waste and keep out of trouble. To hear some directors talk it would almost seem as though they would discharge a man if he owned a slide rule. It has been so firmly insisted upon of late, however, that there is something in this chemistry, after all, that the style may be set some day to have "a chemist" on the board of directors of a manufacturing corporation. American business men, like some of their frailer sisters, are disposed to take "The Easiest Way"; and the easiest way in this connection would be to send down to the works and tell young Brown or Jones or Robinson who may be testing materials in their cupboard of a laboratory somewhere under the stairs, to come up to the office and sit in.

Then suppose the most affluent, the most pompous, the vainest if not the richest director, the father-in-law of the secretary of The Sand & Stone Co., were to offer the following motion: "Resolved, that, prices being equal, this corporation shall purchase its rock from The Sand & Stone Co." The young chemist apologizes for speaking and says that Sand & Stone are agents for Blue Mountain rock and that this rock seemed to show traces of Dubium which he fears might give trouble in the works.

"Whatcha mean?" roars the affluent one to the pale B. S.

"Well—I—er— it doesn't seem to me that it works as well as the Earth & Rock Co.'s product that I believe comes from Green Mountain. I thought I found traces of Dubium there, and, you know, there might be a catalytic effect——"

"Cataclysmic Effect!" exclaims the affluent one. "Young man, is that what you think or what you guess?"

"Why, I'm not sure but I think——"

"That's what you think, is it? Well, sir, when you know something let's hear from you, but we don't care for any of your guesses. The Sand & Stone Co. are the largest dealers in this material in the world and if I tell them to send us rock without any of this here Dubium in it, they'll send it. I call for my motion, Mr. Chairman."

The motion is put and carried.

In one year's time the asset of the corporation's name as a trademark becomes a liability; they cannot persuade people that their product is not tainted. Even after they have seen the folly of their ways and given up the use of Blue Mountain rock and turn out a product better than ever before, their reputation is still bad.

"Better not buy of 'em," says one customer to a prospective one. "They tried to run off a lot of inferior material on me, but I made 'em take it back."

"One of their drummers was in not long ago and he said they had had a fault but had corrected it; they had some Dubium in their rock they make it of, but he says it's all right now."

"That's what they say! Jever know a concern that wasn't all right when they wanted to make a sale?"

"That's so. Better be on the safe side," says Mr. Prospective Customer, and he buys from the rival company.

Now suppose instead of electing the young chemist from the works, a consulting chemist of standing is selected, retained and added to the board to avoid mistakes *at the start*, which is the Grand Economy. Let us imagine the same corporation, same chairman and president, same pompous old party with a son-in-law with Sand & Stone, same general counsel and the same other members except that Dr. Noyadont of the Noyadont Laboratories sits in the place of young Brown, the

chemist at the works. Unlike Brown, Dr. Noyadont has not bought himself a house in the neighborhood of the factory and has not married on the prospects of the good-will of the very board of which he is a member. Dr. Noyadont likes his annual retainer, which may be more than Brown's salary, but he does not live on it. Then let us imagine the same proposal of the affluent Mr. Fatwad that the corporation procure its rock from Sand & Stone.

Dr. Noyadont speaks up: "Sorry, Mr. Fatwad, but I shall have to oppose that motion. I've examined the Blue Mountain rock that they handle and it is not good for our purpose."

"Why not?"

"Appears to be Dubium in it."

"But these people are the largest producers of rock in the world and do you mean to tell me——?"

"I mean to tell you not to use any Blue Mountain rock. It's the best there is for some purposes, but not for us."

Old Fatwad observes that Dr. Noyadont is neither afraid nor uncertain of his ground. But he likes to have his way and he proposes a committee of three including Dr. Noyadont to ascertain—

"No occasion for me to look into it any more," says Dr. Noyadont. "Go ahead and buy all the Blue Mountain rock you want to," he continues, "but with it comes my resignation from the Board and from the office of your consulting chemist. Mr. Fatwad expects your processes to move on all calm and serene in the presence of a catalytic agent that may start up all sorts of reactions that you don't want. I can't be sure of your product under those conditions. If some member of the board were to propose to break the laws of the state or the nation, your General Counsel here would advise you against it, and if you were to persist in it he would resign. Well, here you propose to break Nature's laws and expect to keep out of trouble after you've done it. I call for the question, Mr. Chairman, because it involves a matter about which we should not be in doubt for one minute. And I offer my resignation now to take effect as soon as the motion is carried."

Mr. Fatwad then withdraws his motion. He may see a light and again he may not, but the chances are that he will, because he is nobody's fool. But rich-man's vanity is one of the most difficult things to overcome. When it is quiescent it is invisible and harmless; when it is active it is hard to endure and highly dangerous. The only way to deal with it when it is active is to whack it on the head. No employee can do this without providing for himself first, a good, safe runway into the tall timber.

There should be a chemist on the board of every corporation that has to do with chemical processes. He should be a man of attainment, of distinction and of backbone.

ELLWOOD HENDRICK.

New York City.

Engineers Interested in Preparedness.—The Monday night lectures given at the Engineering Societies Building, 29 West Thirty-ninth Street, New York, on military subjects under the direction of Maj. Gen. Leonard Wood are attracting large audiences. On the first Monday night, Feb. 14, more than 2300 engineers tried to attend. It was necessary to turn between 500 and 1000 away, even after holding an overflow meeting for 500 in a separate hall, where the same lecture was given as in the big auditorium but by another army engineer. The speaker in the large auditorium was Capt. Thomas M. Robins, who spoke on the duties of engineers in war, and what engineers in civil life will be called upon to do.

The Power Famine at Niagara

Meeting of Niagara Falls Section of American Electrochemical Society

(From Our Special Correspondent)

The Niagara Falls section of the American Electrochemical Society discussed the power situation at Niagara Falls at its February meeting, held at the Assembly Room of the Niagara Electric Service Corporation on the evening of February 2. A large and representative body of Niagara Falls electrochemists was present, and the proceedings were marked by a definiteness of purpose and intensity of interest of quite unusual order.

The chairman, **F. A. Lidbury**, opened the meeting with an explanation of the reasons for which it had been called. He pointed out that those present had long foreseen that the governmental restriction of power development at Niagara must ultimately result in the present situation, in which the shortage of power was seriously hampering the electrochemical industries and through them the industries of the country at large. Individual members had done what they could from time to time to point this out publicly, but there had been no concerted effort. It was time for this condition to cease and for members to stand together and to do whatever was possible to bring about such changes as would relieve the situation.

What the section could do was the main matter for discussion. He thought himself that its usefulness would be largely educational. Firstly, they had to educate themselves as to the situation. This was the main object of the meeting. Very few knew, for instance, how much power was generated on this side of the Niagara border, and how much imported from Canada; how much of the total amount was used for electrochemical purposes, how much for other. Secondly, they had to educate the local community; there ought to be a better realization of the dependence of the city's growth and prosperity on a continually increasing power development; thirdly, he pointed out the growing influence of technical societies and advised the education among their own and related societies of members as to the national importance of the matter; and, fourthly, they had to attempt to educate the people at large, who were fully awake to the significance of the dye situation, but quite ignorant of the far greater importance of the electrochemical industries, because the matter had not been properly brought to their attention. He asked F. L. Lovelace of the Niagara Falls Power Company and J. L. Harper of the Hydraulic Power Company to explain the present situation to the meeting.

F. L. Lovelace gave an interesting historical sketch of the power development at Niagara and of legislative acts restricting it. He contended that the limits set by the Burton Act, which limits were at present being insisted upon by the government in spite of the fact that the Burton Act had expired and the treaty with Canada allowed 4400 cu. ft. sec. more, were unfair to the Niagara Falls Power Company and that it had been the intention of the treaty convention in extending these limits to correct an error in the Burton law so as to permit the operation to full capacity of the plant of the Niagara Falls Power Company. He concluded with an analysis of the Kline bill now before Congress and showed that the result of this bill would be not only to make operation more difficult and restricted, but to place the whole of the present developments in jeopardy.

If Mr. Lovelace's address was, perhaps naturally, rather a piece of special pleading on behalf of the

Niagara Falls Power Company, that of **J. L. Harper**, who followed, dealt in an extremely witty manner with the situation from the point of view of the Hydraulic Power Company, Mr. Harper ironically thanking that company for their efforts to secure the extension of diversion limits from the 15,600 ft. of the Burton Act to the 20,000 of the treaty. He sarcastically observed that the "growing influence of technical societies" might result in such control of meteorological conditions that ice troubles resulting in intermittent service might be avoided. He appeared to think that much influence might be exerted by associations of industries dependent upon electrochemical products—this, one presumes, on public opinion and legislation, not on ice. Two points from his remarks aroused general interest—first, his admission that "if the power companies had been together in anything beside their woes, conditions might have been very different;" secondly, his estimate that the total flow of the falls represented about 5,000,000 hp., and his contention that a suitable system of submerged weirs could so distribute the flow as to render 60 per cent available for power purposes and provide a grander spectacle than at present with the remaining 40 per cent, while at the same time diminishing the natural erosion at the peak of the horseshoe where the large volume of water is now running over without assisting the spectacle in the least, but resulting in the recession which tends to denude the remaining portions of the fall of water.

In answer to a question Mr. Harper said that the Niagara Falls Power Company generated 90,000 hp. and the Hydraulic Power Company 100,000 to 125,000. All the latter, except 15,000 hp., was employed in the electrochemical industries.

F. J. Tone, who followed, spoke on the subject of *Niagara Power and Industrial Self-Containedness.*

This concise statement would lose so much by summarizing that it is quoted in full:

If the year 1915 has shown us one thing more clearly than another, it is that a nation must be economically and industrially independent. Some of our economists have told us from time to time that a nation should not strive to be self-contained; that America should confine itself to the development of its most abundant resources, for example, those of agriculture, lumber, coal and the heavy manufacture of iron and steel, and that we should let Germany supply us with our potash, dyestuffs and fine chemicals, England with our ferromanganese and Chile with our nitrates.

The year 1915 has shown us to what economic distress such a policy leads. We have seen crude potash advance from $35.00 to $400.00 per ton—a point where its use as a fertilizer has practically ceased. We have seen England place an embargo on ferromanganese and the price advance from $38.00 to $125.00 per ton. Magnesia, the basic refractory of the steel manufacturer, has become almost unobtainable, and the same may be said of numberless commodities, including emery, barytes, carbolic acid, crucible graphite, platinum and dyestuffs.

I wish to point out a few ways in which the whole question is bound up in Niagara power, and to show the paralysis of industry that would follow if the electrochemical companies of Niagara Falls could not continue to meet the call that is being made on them. Few realize how many industries are directly dependent on chemistry. Still less has it been realized to what extent our great basic American industries depend on electrochemistry, and specifically on the electrochemical products of Niagara power.

I first wish to mention the steel industry. The manufacturers of steel, the greatest of all American industries, are to-day absolutely dependent upon Niagara power by reason of its requirements in ferro-alloys, such as ferrosilicon, silicon metal, ferrochrome and ferrovanadium. In 1915 there was produced in this country about 28,000,000 tons of steel, 20,000,000 tons of which was basic open-hearth steel, and in 75 per cent of this there was used as the main deoxidizing agent high-grade ferrosilicon produced in the electric furnace by Niagara power. All ferrosilicon made by electric furnaces in America is now produced from Niagara power. It is an absolutely essential element in 15,000,000 tons of steel.

The most striking example, however, of the intimate relationship between the metal working industries and Niagara power is that of high-speed steel. The essential alloys in the manufacture of high-speed steel are ferrochromium, ferrotungsten and ferrovanadium. All of these are produced in Niagara, and they are also made elsewhere by the use as reducing agent of metallic aluminium, likewise a product of Niagara power. If the supply of high-speed tool steel were cut off there are hundreds of metalworking industries where the output would be reduced to 25 per cent of their present rate.

Ferrochrome is also the hardening element in armor plate and armor-piercing projectiles, and not a battleship is afloat but what has many tons of it in her armor; yet up to three years ago we were dependent on Europe for one-half of our supply.

In other special steels, such as silicon steel or electrical transformer steel, we also find an almost total dependence on the products of Niagara power.

The abrasive industry is one intimately connected with industrial life. Without adequate grinding materials the most important industries of the country, including the manufacture of automobiles, agricultural machinery, steel and malleable iron, marble, granite and all finished products of iron and steel, would be greatly handicapped and in cases their output would be reduced to a fraction of their present rate. The abrasive situation to-day is another striking illustration of the dependence of industry on Niagara power.

Abrasives are of two kinds; the natural abrasives, which are Turkish and Grecian emery, and the artificial abrasives, such as carborundum, alundum and aloxite. Ten years ago artificial abrasives represented 22 per cent of the total consumption. In the year 1914 they represented 55 per cent. Since the war, however, the mining of emery has almost ceased. Not a pound of Turkish emery is being shipped, and shipments from Greece are negligible.

There are four artificial abrasive plants operating with Niagara power, and they produce all the artificial abrasives used in this country. Their annual output is about 20,000 tons. If this supply were cut off a partial paralysis would follow throughout the metalworking industries.

As an example, take the automobile industry. One of the big western manufacturers plans during 1916 to put out 1000 cars per day. In the factories of that company grinding machines form about 25 per cent of the tool equipment. The crank shafts are roughed and finished with grinding wheels, the cylinders are bored with grinding wheels, balls and ball bearings cannot be produced without grinding wheels. It takes 500 wheels per month to grind forgings alone. If we could conceive that these works were forced to go back to the grindstone and were at the same time deprived of high-speed tool steel, aluminium, oxyacetylene welding and other products produced by Niagara power, it is not an exaggeration to say that their output would drop from 1000 to 100 cars per day, with the same plant equipment and the same number of workmen. The cost of the car would be multiplied by ten, which simply means that there would be no automobile industry.

Aluminium and calcium carbide, the largest of the electrochemical industries from the point of the power consumed and value of the products, were first made possible by Niagara power, and on these products, as well as other Niagara products, such as bleaching powder, alkali, chlorine, phosphorus, graphite, sodium and cyanides, depends a whole line of America's basic industries.

To-day nitrogen products are unquestionably the most important products in the field of chemistry. Without them modern warfare, as we know it, would be impossible, because they are an essential element in every explosive.

The success of Germany in making herself independent of Chilean nitrates in a single year is an industrial achievement of the highest order, but nitrates are not merely a war product. They are necessary in the life of an agricultural nation at all times and, as a matter of common foresight, the production of artificial nitrates should to-day be made an established industry in America. This does not mean that we should at once produce all the nitrates required, but partial development should be encouraged, which would enable the industry to be perfected in its chemical and technical organization so that it could meet any natural or political emergency. This at once calls for cheap electrical power in the center of good transportation facilities, and, in brief terms, it means that we must have Niagara power in large amounts and at low cost.

The only nitrogen fixation works operated by Niagara power is the American Cyanamid Company, and this pioneer industry was forced to go to the Canadian side to obtain

sufficient power. America has 25,000 horsepower devoted to nitrogen fixation and Europe over 300,000 horsepower. We are startled when we are told that for the spectacle of Niagara we are paying the price of a million tons of coal a week. I believe it is more startling to put this in terms of America's food supply. If Niagara was devoted to the production of nitrogen fertilizer it would produce sufficient nitrogen for 3,000,000 bushels of wheat per day.

In any program of industrial preparedness and self-containedness chemical preparedness and chemical self-containedness play a big part, and its crux is more Niagara power.

L. E. Saunders elicited from **P. P. Barton** of the Niagara Falls Power Company the statement that from 125,000 to 150,000 hp. was being transmitted into the United States from the power stations on the Canadian side at Niagara Falls. Mr. Saunders pointed out that this importation depended on permits revocable by the Canadian government, and indicated that the revocation of these permits was not so distant as peopled imagined. The generation of large quantities of additional power at Niagara *on the American side*, and rapidly, was the only way by which a frightful dislocation of American industry could be avoided.

H. R. Carveth stated that it was necessary, as development of power had been restricted by popular voice, and as popular opinion traveled as a pendulum swings, to take advantage of the return swing from the influence of the J. Horace MacFarland *Ladies' Home Journal* agitation. It was a question whether the return swing had already started or not.

NIAGARA FALLS POWER AS A NATIONAL DEFENSE NECESSITY

Albert H. Hooker spoke of the present campaign for national preparedness, and considered a much larger development of Niagara Falls power as a national defense necessity.

The largest industries of the country, steel, paper and chemicals, now find these electrochemical products vital raw materials without which they cannot operate. Many of these products so useful in times of peace are called for in vastly larger quantities in times of war. Not only the equipment, but the skilled electrochemists, mechanical engineers and operators are needed for the manufacture of these products. The provision of such skilled labor in these specialized industries in times of peace, as an emergency measure, is fully as important as compulsory military service and should be considered as a branch of the same broad plan. As regards the electrochemical industry such development could only take place where economic conditions were favorable for the economical production of power of the highest commercial value. For this industry, Niagara Falls occupied first rank and now holds first place as the world center of the industry, with the greatest force of active workers in this field anywhere in the world.

Even now some of our industries were compelled through lack of power to move to Norway and other fields, while unused water which could be consumed without injury went to waste and we start the training of a foreign army of electrochemical workers on foreign soil.

Germany's interest in the electrochemical industry and the fixation of nitrogen has been her salvation at this time, and we should consider her interest in the dye industry as a measure of preparedness. The same benzol, toluol, caustic soda, nitric acid, chlorine and sulphuric acid used in times of peace in the manufacture of dyes are used in times of war for the various nitro explosives; the same equipment is used and the same army of skilled chemists and workers familiar with the latest details of nitration processes are in constant training. Should we not consider the training of this industrial army and the development of our water power and electrochemical industries as of particular importance now as a matter of preparedness in National Defense?

After some further discussion, on the motion of Mr. Saunders, the chairman appointed a committee of the Section to deal with the matter along the lines suggested in the discussion. The chairman appointed F. J. Tone (chairman), H. R. Carveth, I. R. Edmands, F. A. J. FitzGerald, A. H. Hooker, H. W. Kellogg, W. S. Landis, F. A. Lidbury, C. H. Moritz, L. E. Saunders, W. A. Smith, A. T. Hinckley (secretary).

The Western Metallurgical Field

Potash from Kelp

The Hercules Powder Company has let a contract to Charles C. Moore & Company of over $500,000 for the erection of a kelp plant in San Diego, Cal.

Swift & Company are also building a new potash plant at San Diego, having completed their experimental work in the plant which they leased for that purpose in San Diego.

Cooperation Between U. S. Bureau of Mines and Colorado School of Mines

On Jan. 29, 1916, a cooperative agreement was signed by Van H. Manning, director of the United States Bureau of Mines, and William B. Phillips, president of the Colorado School of Mines, which is expected to react to the benefit of both parties and to aid in the metallurgical development of the State. The present Denver office of the bureau is to be removed to Golden next June, and thereafter metallurgical research will be conducted under joint auspices. Under the terms of the agreement the school offers the bureau the use of the building known as Engineering Hall, which will be slightly remodeled to meet the bureau's needs.

This arrangement has been concluded with the object of avoiding duplication of work; to obtain an interchange of information; and to cooperate in the conduct of investigations having particular reference to the development and utilization of the mineral resources of Colorado and the West. The experimental mill and testing plant of the school will be available for this work as far as may be necessary, and in general the laboratory and library facilities will be at the disposal of the bureau.

Details of the work that will be undertaken and the exact method of cooperation have not yet been determined, and will be left to the discretion of the proper officials of the school and the bureau. It is recognized by all concerned that the success of the arrangement depends on active and genuine cooperation, and it is expected that harmonious relations will be established and that the industry will profit from the close contact of these two centers of metallurgical research.

Improved Industrial Relations in Colorado

The marked change that has come over the spirit of capital and labor in Colorado since the war-like conditions of 1914 is reflected in the *Industrial Bulletin* of the Colorado Fuel & Iron Co. This company is one of the largest employers of labor in Colorado, operating numerous coal mines and the Minnequa steel works at Pueblo. In former years there has been more or less disagreement between the company and its employees, culminating in actual warfare two years ago this spring. Echos of those conditions are still heard in the courts, where miners are being tried for their part in the destruction of life and property.

Apparently a new day has dawned, and employer and employee are going to understand each other better.

They are coming to a belated recognition of the rights of each, and of the necessity for cooperation for mutual good. It will be remembered that out of the strife of 1914 grew a proposal of the junior Rockefeller for industrial representation among employees and company officials, for the purpose of harmonizing differences of opinion. That plan is now being put into effect, and conferences have been held. The president of the company has appointed an "industrial representative" for mines and one for the steel works, their duties being indicated by their official titles.

In the January issue of the company's *Industrial Bulletin* we note an editorial on "Democracy in Industry," from which we quote a few lines that show the tenor of the new relations: "The growth of large corporations seems to demand some such step as a means of insuring justice to every employee. In large measure this plan brings all employees of the company into close relations with the officers, somewhat as was possible in the old days when the individual employer with a small group of employees took a personal interest in the welfare of each member of his business family. There are many honest critics who regard this as paternalism and as doomed to failure. But there is every evidence that C. F. & I employees believe that a real partnership of these two interests is possible—a partnership based on friendship, mutual interest and fair dealing. This company is squarely committed to democracy, as contrasted with paternalism, in all its relations with its employees."

Engineering Research Proposed for Columbia

In the annual report of Dean F. A. Goetze of Columbia University he discusses the proposition of establishing at Columbia an engineering research laboratory similar to those in Germany which he visited some time ago. The proposed scheme is pretentious and involves the expenditure of about $500,000 for building and equipment, and an endowment of from two million to five million dollars. In comparing the relative cost and value of the proposed engineering research laboratory with that of the proposed building for applied science on the university site, Dean Goetze states that "with the same amount of money we could buy a site with railroad and water facilities within five minutes' walk of the university, erect on it a building twice the size, of a modern factory construction much better suited to our purposes, and have about $150,000 left over for equipment." After speaking of the endowment he expresses the opinion that "no other university is so favorably situated by its environment, prestige and traditions to lead in this important field."

Conditions in Mexico

The recent massacre of members of an engineering party in Mexico has acted as a bar to the early resumption of work at some mines. The conditions which resulted in this sad incident have not been confined to any one part of the country, and bandits are active wherever they feel reasonably secure from molestation by agents of the *de facto* government. In a recent letter from an engineer now at Guadalajara, commenting on the fate of the engineers in Chihuahua, he says: "We walked into a trap like those poor devils did, but thanks to four of our men who learned of it in time and who caught the bandits in the rear just as they were about to attack us, we got away and back to Ixtlan, while the bandits scattered after losing one man. We got an escort and returned, but found none awaiting us that trip." Such conditions speak for themselves and show what prospect American engineers have in starting or continuing mining and milling operations in Mexico. It is more than likely that such conditions will prevail for some time to come, and life and property will be in jeopardy. Sporadic outbreaks will occur, becoming less frequent as time goes on, with bandits pillaging and murdering, until the government becomes strong enough to insure peace. In the meantime American engineers apparently are without assurance of safety while remaining or traveling in Mexico.

Company Reports

The seventh annual report of **Stratton's Independence, Ltd.**, contains a resume of operations for the seven years of the company's existence, and an interesting comparison of the results actually obtained with those anticipated by the original tests of the dump. For the year ended June 30, 1915, the mill treated 116,778 tons of ore, of which 74,849 tons came from the old dump and the balance from the mine. The average gold content was but 0.1468 oz. per ton. There was recovered in concentrates 37.31 per cent of the total, and in bullion 38.66 per cent, or a total of 75.97 per cent. The first-grade concentrate averaged 4.031 oz. gold per ton and the second-grade 1.61 oz. These products were sold to smelters. The following table gives a summary of milling cost:

Operation	Per Ton
Coarse crushing and sorting	$0.199
Fine crushing, concentrating and treating concentrate	0.515
Cyaniding and special chemicals	0.478
Miscellaneous expense	0.171
Total milling cost	$1.363
Mining dump ore	0.150
Total cost	$1.513

Compared with the previous year the tonnage treated was less, the extraction lower and the cost higher.

Mr. Argall, consulting engineer, who originally recommended the construction of the mill and the treatment of dump ore, adds some figures to show how his estimates have been confirmed in practice. The estimated value of the dump ore, obtained through the expenditure of $9,500 for sampling, was assumed to be $3.60 per ton. Based on a 70 per cent extraction and an operating cost of $1.52 per ton, Mr. Argall believed that a net profit of $1 per ton could be made. A summary of six years' milling operations shows the treatment of 671,665 tons of ore containing an average of 0.1522 oz. gold per ton, yielding an average extraction of 74.57 per cent at a cost of $1.5138 per ton. Thus it is seen that the average value of the ore was slightly lower than the estimate; the recovery was considerably higher and the cost slightly lower. If a monthly tonnage of 10,000 tons had been treated continuously the net profit of $1 would have been fully realized.

Throughout its history to the date of sale to the Portland Gold Mining Co., Stratton's Independence mine produced ore of a gross value of $23,621,728, yielding earnings amounting to $8,116,778. The present company paid in dividends $455,625 and had cash on hand, after selling the property for $372,000, amounting to $510,000. Having closed its business in the Cripple Creek district of Colorado, the company is now looking for a new property.

The report of **Camp Bird, Ltd.**, for the period ended June 30, 1915, shows that both profit and tonnage for the year exceed the estimate of a year ago, and that there still remains in reserve a profit almost equal to the estimate of a year ago. Cost of both mining and milling are lower by 12 cents per ton each than they were during the previous year. The total cost of operation is lower by 98 cents per ton. The profit amounted to $583,700, an increase of $186,380 over the preceding year. The mills were in operation 357 days, and the saving was 96.03 per cent of the gold value and

94.31 per cent of the combined gold and silver value. Of the total recovery, amalgamation yielded 58.48 per cent; concentration, 36.59 per cent; cyanidation, 4.93 per cent. The recovery of metals per ton of ore averaged 1.333 oz. gold, 3.78 oz. silver, 1.048 per cent lead and 0.16 per cent copper. The value per ton of the recovered metals was $29.47, as compared with $26.19 last year. The amalgamation and concentration mill treated 32,313 dry tons of ore. The cyanide mill treated 20,655 tons of tailings from amalgamation and concentration. Dividends paid amounted to £100,476 ($487,308).

The Santa Gertrudis Co., Ltd., states in its annual report for the period ended June 30, 1915, that operations at the property in Mexico have been practically continuous under the adverse conditions that have existed. Development work has continued, and the ore reserves are estimated at 1,287,000 dry tons, sufficient to last about three and a half years under normal conditions of production. The estimated metal content in the ore reserves is 81,086 oz. gold, and 16,217,296 oz. silver, 90 per cent of which is recoverable. The Guadalupe mill remained closed during the year, although 268 flasks, or 10.09 tons of quicksilver was recovered from the old patio. Work at the new mill has been far below capacity owing to the difficulty of obtaining supplies. The gross tonnage treated amounted to 211,669 dry tons of ore having a gross value of 26s. 2d. ($6.28) per ton. The recovery in bullion amounted to 90.31 per cent of the gross value. The average daily tonnage treated was 580 dry tons, compared with full capacity of 1111 tons.

The Coniagas Mines, Ltd., in common with other producers of silver, suffered from the reduced demand and lower price of that metal in 1915, according to the annual report for the period ended Oct. 31, 1915. The concentrating mill at Cobalt, Ontario, ran 98.83 per cent of the possible time, milling 55,437 tons of ore, at the rate of 3.02 tons per stamp per 24 hours. The average silver content was 23 oz. per ton. High-grade silver concentrates amounted to 473.9 tons, containing 2175 oz. silver per ton. Low-grade slime, averaging 233 oz. silver per ton, amounted to 133 dry tons. Sand tailing contained 2.89 oz. silver, while slime tailing carried 6.36 oz. per ton. The average tailing carried 3.94 oz. The high-grade mine ore shipped amounted to 267 dry tons, containing an average of 3520 oz. silver per ton. Total shipments of silver for the year amounted to 2,002,053 oz. The cost of mining and concentrating was 13.618 cents per ounce of silver produced. The cost of shipping, smelting, refining and marketing was 3.252 cents per ounce. Dividends amounting to 21 per cent, or $840,000, were paid. Silver reserves are estimated at over ten million ounces. An addition to the mill is under construction for the purpose of cyaniding about 6 tons per day of low-grade canvas table concentrates and decomposed slime or gouge from the mine. It is estimated that this plant will effect a saving of about $100 per day.

The Consolidated Mining & Smelting Company of Canada, Ltd., made a net profit of $795,411 during the year ended Sept. 30, 1915, after writing off $192,479 for depreciation. Dividends amounting to 8 per cent, or $464,398, were paid, leaving a balance of $331,013. The total credit to profit and loss account is $2,058,300. Important additions have been made at the smelter to provide for the production of refined zinc and copper. The manufacture of zinc is a new departure, but is expected to develop into an important feature of the company's operations. Copper matte, hitherto refined in the United States, is to be refined in Canada. Further improvements consisted in purchase of the right to use the Cottrell process of fume recovery for roasters and blast furnaces; construction of an additional lead furnace; construction of a new lead sampling mill. The experimental electrolytic zinc plant was operated during the year, producing spelter of good grade at the rate of ½ ton per day. A permanent plant of about 35 tons daily capacity is now under construction. Smelter production for the year amounted to 148,891 oz. gold, 2,230,500 oz. silver, 40,177,910 lb. lead, 5,306,184 lb. copper, all from 447,064 tons of ore and of a gross value of $6,898,744.

The Iron and Steel Market

Steel prices have advanced during the past fortnight more rapidly than ever. On Feb. 15 steel pipe and line pipe, 12-in. and under, was advanced one point or about $2 a ton, oil country goods being advanced $2 to $4 a ton, while wrought-iron pipe was likewise advanced $2 a ton. At about the same time wire products were advanced $2 a ton. On Feb. 17 the Carnegie Steel Company advanced bars, plates, shapes and hoops $5 a ton, previous advances having generally been $1 or $2 a ton, and other mills immediately followed in this action. The price of $3.75 on tin plate, which had been gradually disappearing, became altogether nominal, yielding to an actual market of $4 to $4.25 for 100-lb. cokes.

The attitude of the mills in advancing prices so sharply, when they were already at the highest level in a dozen years or more, is not clearly disclosed. As a rule when the mills advance prices it is because they have booked all the business they care to book at a certain level but are prepared to book a considerable additional tonnage at a higher figure. In this instance they are still reserved about selling. Either they expect practically fabulous prices to be paid for large tonnages of steel in future or they feel that a break in prices would not be the formidable event it usually is.

The average price of finished steel products, including bars, plates, shapes, pipe, wire, sheets and tin plate, weighted approximately according to their tonnage importance, has advanced from 1.42c. in December, 1914, when the lowest level in fifteen years obtained, to 2.07c. at the close of 1915, equal to the average level of 1907, and to 2.42c. at the present time, representing a total advance of $20 per net ton, two-thirds of the advance having occurred during 1915 and one-third during the first two months of this year.

There is a divergence in the extent to which the mills are definitely sold up and the extent to which they are committed to customers. The Steel Corporation's statement of unfilled obligations at the end of February, to be made public March 10, will probably show it sold up, on an average, to the latter part of September. It is not certain that all the tonnage will actually be taken by customers, while on the other hand there are promises to take care of regular customers, representing important additional obligations which preclude the acceptance of much tonnage from new buyers. Many steel buyers appear to be quite fearful that the regular sources of supply will be unable to furnish them all the steel needed during the second half of the year.

Pig-iron production is at the rate of about 39,000,000 gross tons a year, production of ingots and castings at the rate of about 41,000,000 tons, and production of finished rolled steel at the rate of about 29,000,000 tons. The production of pig iron has been a surprise for months, or ever since it passed a rate of 36,000,000 tons, representing approximately the estimates made of the existing capacity, based on performance the last time the industry was really active. The blast furnaces have outdone themselves. A large part of the excess production appears to be due to the fact that many furnaces have been provided with larger hearths, the change bringing about a larger output without a corre-

sponding increase in either the air or coke supplied. There was a time when predictions were made that on account of the heavy building of open-hearth furnaces without the erection of a corresponding number of blast furnaces a shortage in pig iron would occur before a shortage in steel, but the history of the market to date is that finished steel products have advanced an average of $20 a net ton while pig iron has advanced an average of $5.50 a gross ton. Comparisons made for the top prices of 1907, 1909 and 1912 show advances in pig iron not dissimilar to the advances in steel.

Pig Iron

The extreme dullness that characterized the pig-iron market for about two months has been suddenly broken in the past fortnight, with respect to steel-making iron. There were large purchases in the East, followed by several important purchases in the Central West, and in the latter region there was also a fair turnover in northern and southern foundry iron, the movement to date representing possibly about a quarter million tons. Prices have not advanced definitely, but consumers have become much more interested. The balance between production and consumption is a very delicate one, with few idle furnaces that are at all fit, and much open-hearth steel capacity under construction. The steel works have small stocks, but may conclude that in such uncertain times as these, and with steel prices advancing by leaps and bounds, it would be prudent to build up reserves. In some quarters there are predictions that pig iron will advance by leaps and bounds, once buyers conclude to act against the possible dangers, and it may be noted that while the furnaces have passed through an apparently trying period of market stagnation they are decidedly reserved about selling. We quote: No. 2 foundry iron, delivered Philadelphia, $19.75 to $20.25; f.o.b. furnace, Buffalo, $18 to $18.50; delivered Cleveland, $18.80; f.o.b. furnace, Chicago, $18.50 to $19; f.o.b. Birmingham, $14.50 to $15; f.o.b. valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, $20; basic, $18; forge, $18; malleable, $18 to $18.50; No. 2 foundry, $18.50.

Ferromanganese is extremely scarce, bringing $225 to $250 for small prompt lots, while the contract price for English, second half or fourth quarter, is $150, with some English producers not quoting at all.

Steel

The demand for unfinished steel has broadened somewhat, as premiums are obtainable for some descriptions of finished steel, the regular mill prices on finished steel, for forward delivery, not being high enough to justify finishing mills paying prices that would be asked for unfinished steel in the open market. Such mills, are, of course, moderately well covered by contracts. As fairly representing the market in general $35 may be quoted for Bessemer and $38 for open-hearth, either billets or sheet bars, f.o.b. maker's mill, Pittsburgh or Youngstown. Rods have advanced to $50, for deliveries beginning a few months hence, and a few sales have been made at this remarkable figure, which is higher per pound than the regular market on plain wire.

Finished Steel

Regular prices given below are f.o.b. Pittsburgh, unless otherwise noted, and for delivery at mill convenience, the higher in a range of prices being for early delivery of small lots.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 2.35c. to 3c.

Structural shapes, 2.25c.

Steel bars and bands, 2.25c. to 2.75c., base; steel hoops, 2.50c., base.

Iron bars, Philadelphia, 2.409c.; Pittsburgh, 2.20c. to 2.30c.; Chicago. 1.90c. to 2c.

Plain wire, 2.15c., base; galvanized wire, 2.85c.; wire nails, $2.30, base; painted barb wire, 2.45c.; galvanized barb wire, 3.15c.

Sheets, blue annealed, 10-gage, 2.65c. for Bessemer, 2.75c. for open-hearth; black, 28-gage, 2.60c.; galvanized, 4.75c. to 5c. basis.

Tin plate, $4 to $4.25 for 100-lb. cokes.

Steel pipes, ¾ to 3-in., 75 per cent off list; galvanized, 59½ per cent off list.

Boiler tubes (less than carloads), 64 per cent off list for steel, 60 per cent off list for iron.

Structural rivets, 3c.; boiler rivets, 3.10c.; cold rolled shafting, 40 to 35 per cent off list; cold rolled strip steel, 4c., base.

Continuous Operation of Engine-Driven Electrolytic Generators

The following table gives the number of hours of operation and the percentage of time that generators were in service at the Raritan Copper Works, Perth Amboy, N. J., from August to December, 1915.

Month	Total Hours in Month	Engine No. 1		Engine No. 2		Engine No. 5		Engine No. 6		Per Cent Total All Engines
		Hours in Operation	Per Cent	Hours in Operation	Per Cent	Hours in Operation	Per Cent	Hours in Operation	Per Cent	
Aug.	744	662	89	575.25	77	740.25	99.7	739	99.2	91.5
Sept.	720	719.5	99.9	705.25	98	703	97.6	715	99.4	98.6
Oct.	744	713	96	718	96.5	726.5	97.5	724.5	97.5	97
Nov.	720	691.25	96.1	698	97	696	97	683.6	95.0	96
Dec.	744	732.6	98.5	733.25	98.5	740.5	99.8	742.25	99.9	99
	3672	3518.35	96.0	3429.75	93.4	3606.25	98.5	3604.35	98.2	96.4

The engines are four-cylinder, triple-expansion, Corliss size 21, 38, 44 and 44 by 48, driving 900-kw. generators and were built by the Nordberg Manufacturing Co., Milwaukee, Wis.

The engines, as noted in the table, operated in most cases over 95 per cent of the time, averaging out of the total time in five months 96.4 per cent continuous operation. The time lost was for the most part in keying up and taking up lost motion in valve gears.

The chief engineer of the Raritan Copper Works is Mr. George L. Fales, to whom a large share of the credit for this operating record is due.

Non-Ferrous Metal Market

Copper.—The strained situation in copper continues. The prices here are the highest since 1873. Producers are unable to supply any copper before April or May and in some cases later. Third quarter deliveries are being contracted for. July and August deliveries are quoted at 27¼c. with spot at 28c.

Tin.—A rise of 2 cents per pound has been recorded and Straits tin is now quoted at 43.25 f.o.b. New York. The market is very irregular and no consistent demand has arisen although good buying takes place spasmodically. Arrivals up to the 25th were 3752 long tons.

Lead.—Lead still remains in its strong position and in view of the reported demand and sales which are hard to verify the advance made on the 14th to 6.30, New York, was very conservative. This price now rules although another advance would not be surprising.

Spelter.—Spelter is firm and higher. Third quarter is offered at 16½c. eastern St. Louis. Second quarter is

offered at 18c, April at 19c and March at 20c, while spot is quoted at approximately 21c.

Other Metals.—Aluminium is scarce and has risen to 60-61c. There is no relief in sight. Antimony is also hard to obtain as it is claimed that seven-eighths of the arrivals are delivered on contract. The American Daily Metal Market gives the spot price for American, Chinese and Japanese as 43.50—44.50. Silver is quoted at 57. Platinum remains normal at $88 to $100 per ounce, while quicksilver is quoted at $275 to $290 per flask.

New York Meeting of American Institute of Mining Engineers

The one hundred and twelfth meeting of the American Institute of Mining Engineers held in New York City from Feb. 14 to 17, was a great success and very well attended. The newly elected officers as announced at the business session are Dr. L. D. RICKETTS, president; Karl Eilers, J. MacNaughton, T. B. Stearns, C. F. Rand, C. W. Goodale, E. Ludlow and G. B. Barron, directors. The amendment to the constitution raising the dues from $10 to $12 has been adopted. The business session was opened by the masterly presidential address of the retiring president, Mr. W. L. Saunders.

For the arrangement of an unusually attractive program of entertainments and for the vigor with which everything possible was done to make the visitors feel at home and happy, the local committee and its genial chairman, Dr. David H. Browne, deserve the highest praise. The four issues of the *Daily Fume*, published by courtesy of the *Engineering & Mining Journal* furnished much amusement and were greatly appreciated.

The smoker held Tuesday night was a most enjoyable affair and everyone who attended it was enthusiastic in his praise. Mr. L. Addicks had started the arrangements, but sickness prevented him from being present, and the affair was in charge of Mr. David H. Browne and Mr. T. T. Read. There was a most remarkable speaking doll, presented by Mr. Stearns, some grand poetry by Colonel Hay, a metallurgical cow, demonstrated by Mr. Browne, songs, refreshments, and last but not least, a really wonderful experimental lecture on flotation by Mr. Gilbert Rigg, besides a few speeches in more serious mood by some of the oldest members of the Institute. The annual banquet followed by dancing was held on Wednesday night at the Hotel Astor, while the excursion on Thursday on board of the Dolphin was enjoyed by about 200 gentlemen and 100 ladies; despite the inclemency of the weather a delightful time was had by all and many interesting features of the Brooklyn Navy Yard and Sandy Hook proving ground were witnessed. At Sandy Hook a mine was fired but owing to the fog it was not possible to fire the big guns.

The technical sessions were held according to program and all of them quite well attended.

The Relation of Clay to Ore-Dressing and Cyanidation

The presence of clay in so many ores makes a careful study of its relation to metallurgical processes a matter of great importance. A recent contribution on the subject is made by Mr. A. W. ALLEN in *Bulletin* No. 135, Inst. of Min. & Met. Empirical knowledge on the subject of clays in ore-treatment has been gained from the difficulty of settlement, dewatering and filtration, the low recovery of metal, and the problems encountered in classification as a result of the decrease in fluidity of the pulp. The customary explanation has been that oxygen has been absorbed during weathering, resulting in decreased solution-efficiency in cyanide solutions. Later studies have shown the difference between colloidal and non-colloidal clay, and in the former material is recognized the source of much of the trouble in ore treatment. The author confines his discussion to the properties and influence of colloidal clay.

The absorptive powers of clay depend on their colloidal or non-colloidal condition, the former being highly absorbent and the latter practically non-absorbent. The change may be brought about by weathering, when non-absorbent, non-colloidal clay will change to the other form. Adsorption is a different phenomenon, and refers alone to surface concentration of a substance which clay has removed from a solution with which it is in contact. Adsorption undoubtedly occurs with colloidal clay, and metals may be adsorbed. The adsorptive nature of colloidal carbon, which has recently been prepared, when brought into contact with gold-bearing cyanide solution, might well form the basis of research.

The adsorption of metallic gold is an improbability when consideration is paid to the fact that the gold-potassium-cyanide compound is dissociated in the presence of water into K ions and $AuCy_2$ ions. If the latter act as electrolytes by which gold is deposited in place of calcium, then the action is the result of milling in gold-bearing cyanide solution in place of alkaline water, and may be suggested as an explanation to account for the experience of Hutchinson, which is borne out by myself and others, that treatment, after crushing in cyanide solution, necessitates a longer time for the recovery of the gold than is required when the ore is crushed in water and given a preliminary alkaline treatment.

It is also interesting to note that the problem of clarification of solutions after milling-in-cyanide is invariably obtrusive, whereas after milling-in-water trouble is seldom experienced in this direction. In other words, the electrolytic value of gold-bearing cyanide solution is inferior to that of lime water; and when once the slime particles are charged with the former no addition of lime will materially hasten coagulation.

A further and perfectly reasonable assumption may be made, that the gold in the finest condition and associated with the ore may be in the colloidal state. Any clay may actually absorb gold either during or after the process of water absorption. Marshall and Welker have shown that colloidal aluminium hydroxide in the form of a thin jelly is capable of completely absorbing gold from its colloidal solution. This aspect of gold absorption may not need more than passing mention, although it may have a greater bearing on gold recovery processes than we are inclined to admit at the present time.

It is more than likely that gold and silver compounds will be absorbed into the structure of the colloid. Their complete recovery by washing may be either impossible or impractical. Hence our present-day ideas as to the method of distinguishing between dissolved and undissolved gold and silver may have to undergo considerable modification. Metals which cannot be rapidly washed out from colloidal clay may not necessarily be undissolved; and, indeed, it is more than probable that they were, in part at least, first dissolved and later absorbed. This fact is borne out by the results of concentration experiments on slime residue, which have failed to isolate any portion of the material having a higher metal content than any other.

This matter of absorption has a direct bearing on the subject of displacement of dissolved solution from slime pulps.

In wet processes of ore reduction, and when clay compounds are milled and treated in a cyanide solution containing gold, it would seem probable that an absorption of such solution occurs in the honeycomb cells of

the colloid, and that subsequent displacement of this metal must necessarily occupy a much longer time than did its absorption. The absorption is due to direct imbibition, but displacement under normal conditions is probably due to a slow-acting osmotic pressure when the colloid slime is surrounded with wash solution or water. It is also probable that any absorptive equilibrium is only temporary under such conditions, and that cell content varies with the composition of the surrounding medium.

The question arises as to the relative merits of a slow decantation as compared with a rapid filtration process for the removal of the dissolved metal. It would seem that a combination of the two, in the order stated, would be the most efficient.

It is generally recognized among metallurgists that a considerable time of contact is necessary in washing operations with certain classes of ores; and that theoretical displacement figures do not hold good in practice. From what has already been said, it is apparent that time of wash should not always be based on estimates of gold in solution which is apparently dissolved, as compared with gold associated with the ore which is apparently undissolved. In practical work it is generally found that, although the metal which has been dissolved may be apparently replaced fairly rapidly by ordinary means, a further abstraction of metal from ore occurs after prolonged contact with wash solution. This fact would furnish additional evidence that the gold solution so recovered is, in part at least, being drawn from the cells of the colloid slime, and not merely washed off the surfaces of the slime particles.

If we admit the absorptive nature of colloidal clay, we must relegate the phenomenon of adsorption to a position of less prominence than it has hitherto been afforded.

The decrease in fluidity of an ore pulp in wet crushing operations due to inclusion of clay has been observed to have ill effects on the efficiency of classification and concentration. The author suggests the benefit of desliming prior to classification, as well as the use of vertical sided settlers instead of spitzkasten, and vertical sided classifiers instead of cones to prevent the accretion of viscous clay on the sides of the vessels. He also cites the following experience with the settling of a clay pulp: The ore contained considerable clay, both intimately associated and as pellets and balls of plastic material. As the amount of colloid material increased the thickening efficiency of the settlers decreased, and as soon as fine slime commenced overflowing the thickeners all dewatering had stopped and the underflow contained as much moisture as the feed. Classification became completely disorganized and fine sand was so buoyed by the viscosity of the pulp that traversed the radius of the thickeners and overflowed. The particles of clay were in the gel form, and no addition or reduction in the amount of lime had any appreciable effect in hastening settlement. Failure to settle was due to the absorption of large amounts of water by the clay, and although the clay entered the mill as unavoidable waste it left in the residue carrying gold that could not be recovered by ordinary washing methods.

The foregoing ill effects of colloids were corroborated experimentally as follows:

A sample of colloid slime, free from sulphides or organic matter, and carrying neither gold nor silver, was obtained. This was finely pulverized and agitated for six hours with an alkaline cyanide solution of normal cyanide content, and carrying 6.6 dwt. of gold per ton. At the end of this time the pulp was divided into two parts. One portion was drained of surplus solution until the slime carried a moisture percentage of 75, carefully dried, and assayed entire. The result of the assay was 8.2 dwt. per ton, which showed an adsorption and absorption of, approximately, 3.25 dwt. per ton.

The other portion was thoroughly washed with water by numerous decantations. The excess wash was then removed as far as practicable and the residue carefully dried and assayed. The result showed a gold content of 1.8 dwt. per ton.

Three separate samples of the same material were then agitated with alkaline cyanide solution of graduated gold content. After settlement the supernatant solutions were filtered and assayed, and were found to have lost an amount of gold which was in proportion to their original gold content.

If experiments are made with colloidal clay a number of points are noticeable with regard to the question of settlement. The first of these is that coagulation does not take place until after a definite minimum concentration of lime has been reached in the solution. This point of coagulation is generally marked by a distinct color change—a characteristic of colloid transition from the sol to the gel form. An iron-stained slime will lighten in color as soon as the critical point is reached, and the change is often so marked that mill men adopt it as an indication that a sufficiency of lime has been added.

The second point to be noticed is that settlement is slow at all times, but increases from minimum to maximum in direct ratio to the concentration of the lime in the solution. This rate of settlement is hindered if an excess of lime is added.

If caustic soda is used in place of lime we find that it is of considerably less value as an electrolyte; also, that a proportion of the colloid is not precipitated whatever concentration of the solution is aimed at.

In perfectly neutral solutions of colloids in the emulsoid form electrical action is almost absent. In ordinary work, such as the operation of the cyanide process, neutral solutions are seldom or never found; hence we may assume that coagulation and settlement are controlled by electrical action. It will, therefore, be mundane to consider briefly the factors governing the situation.

Lime is generally used as a neutralizer to counteract latent or formed acidity, and it is also used as an electrolyte to ensure coagulation and assist settlement. We have seen how it may and probably does act as a coagulator. This is doubtless due to the combination of the calcium ions with the slime particles. We also know that an excess of lime hinders settlement. This is due to the reduced conductivity which follows concentration of the electrolytic solution.

In summarizing his experience and work the author finds that a complete extraction of gold from even the finest slime is impracticable; that the cyanidation of accumulated clay slime often results in a lower extraction than would have been obtained had the slime been treated directly as made; that the milling a clayey ore in a gold-bearing cyanide solution invariably necessitates longer time for treatment and results in a higher residual metal content than would have been the case had it been milled in alkaline water; that the facts adduced indicate the high absorptive power of colloidal clay, enabling it to retain liquids and dissolved salts. Adsorption may occur during treatment, but the main loss is due to absorption. Non-colloidal clay is only silghtly absorbent; colloidal clay, highly absorbent; burnt clay, after the colloidal envelope has been destroyed, practically non-absorbent. The weathering of clay slime should be avoided unless it is desired to decompose some refractory mineral, and clay slime should be given an extended time of contact with wash solution.

The Effect of Temperature on the Formation of Olefins from Petroleum at Atmospheric Pressure

BY GUSTAV EGLOFF AND THOMAS J. TWOMEY

It is well established that the cracking of petroleum or a high boiling fraction from petroleum in the gas state yields, besides carbon and gas, cracked oil which has a different composition than the material subjected to decomposition.

For the main part its constituents are the four types of hydrocarbons: (1) paraffins; (2) unsaturated compounds—olefins and acetylenes; (3) naphthenes and (4) aromatic compounds. The occurrence of the latter, however, depends necessarily on the conditions of the cracking. The extent to which any one of these classes may be formed is governed by the factors resulting in the decomposition of the original oil, such as nature of the oil, temperature, pressure and time of reaction which is itself controlled by the rate of flow into the heated zone and by the size of the cracking area. Of all these, temperature has perhaps the largest influence and gives the greatest variations in the amounts and in the character of hydrocarbons present in cracked oil. In a previous communication[1] its effect on the formation of the aromatic type—benzene, toluene, xylene, naphthalene and anthracene—was shown. Since it was found that certain temperatures were not only required for the formation but also resulted in definite relationships between these compounds, it was deemed of sufficient importance to investigate still further the influence of the same degrees of heat on the production of another group of hydrocarbons in the same cracked oil—notably the effect on the formation of unsaturated compounds.

According to the available data in the literature the nature of these unsaturated hydrocarbons have been investigated sufficiently to show in a general manner those common to a cracked oil. Thorpe and Young[2] found that paraffin on being distilled under pressure at a high temperature decomposed into liquid compounds of the methane and ethylene series. Among the latter were included amylene, hexylene, etc., up to nonylene. Gawalowski[3] has found recently that paraffin on prolonged heating changed into gaseous and liquid products, which in both cases belonged to the ethylene and acetylene groups. In the investigation of the "hydrocarbon" resulting as a by-product in the manufacture of Pintsch Gas, Armstrong and Miller[4] found olefins—ethylene up to nonylene and also crotonylene. Lewes[5] states that the recovered tar obtained by the cracking of Russian petroleum contained hexylene and heptylene. Kramer and Spilker[6] distilled a lubricating oil (Baku) under pressure and identified olefins in the distillate which was recovered.

From the work of these investigators it appears that the cracking of high boiling fractions of petroleum give low boiling fractions which among other substances contain unsaturated compounds, mainly those of the olefin series. The research to the present date does not seem to show that members of the acetylene series are formed to any great extent.

No specific data could be found in the literature concerning the direct effect of temperature on the unsaturated hydrocarbon formation. Hall[7] states, however, "I can say with all assurance that high temperature makes for high unsaturation." This conclusion was derived from experimental evidence obtained in the operation of his process.

If in cracking an oil by distillation under pressure, the pressure effect may be translated into terms of temperature, a few more examples of the influence of temperature on the unsaturated formation may be had. Distillation under pressure is that type of cracking which takes place in the liquid-gas phase. In this system increased pressure is due to increased temperature. Hence, results obtained by cracking under increased pressure correspond in a manner to those found under increased temperature conditions when the cracking is conducted entirely in the gas phase. In the Burton process the distillate is condensed under pressure because pressure decreases the amount of unsaturation. A statement presented to the United States Patent Examiner gives the sulphuric acid absorption of the Burton distillate as 20.2 per cent and iodine number as 97 against 49.4 and 200 respectively on a similarly cracked distillate condensed without pressure. Brooks[8] found that cracking Oklahoma petroleum under pressure decreased the refining losses in the gasoline cut besides increasing the amount of gasoline formed. The data constitutes the ground for United States Patent 1,101,482.

Scope of the Investigation

In the present paper it was not the intention of showing the influence of temperature on the individual unsaturated formation, but rather on the total formation in certain distillation cuts. In the analysis of cracked oil for aromatic hydrocarbons produced by cracking a distillate or gas oil derived from a Pennsylvania crude petroleum in the gas state at temperatures 450 to 800 deg. C., distillation cuts were made to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C., and 270 deg. C. to Tar.

The object of this investigation was to point out the unsaturated hydrocarbon formation in these cuts. From a combination of values, it was also possible to show: (1) the effect of temperature on the unsaturation in the recovered oil to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C., 270 deg. C. to tar; (2) the unsaturated formation in the gasoline cut—to 150 deg. C. This method of procedure allows one to follow the thermal effect on the formation of the unsaturated hydrocarbons in the cuts and also the extent to which the original paraffin oil on being thermolized decomposed to lower and equally high boiling olefins and similar compounds.

Experimental Part

A distillate or gas oil, boiling between 250 and 350 deg. C., derived from a Pennsylvania crude petroleum was cracked in the gas state by passing through a steel tube at atmospheric pressure. Experiments were run at the following temperatures: 450, 500, 550, 600, 650, 700, 750 and 800 deg. C. The per cent of recovered oil obtained, the gas formation, the specific gravity of the recovered oil, the aromatic content and other data will be found in a previous communication.[9]

The recovered oil from each experiment was distilled using an efficient fractionating column for the lower boiling constituents, and final cuts were made to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C. and 270 deg. to tar.

The per cent of unsaturated compounds in these cuts was determined by means of 95.0 per cent sulphuric acid. The following method of procedure was used: Ten cc. of oil was measured by means of pipette into a Babcock milk bottle, the neck of which was calibrated in

[1] Egloff and Twomey, Jour. Phys. Chem. 20, 121 (1916).
[2] Liebig Ann., 165, 28; Chem. News, 23, 174, 1871.
[3] Oesterr Chem. Techn. Ztg., 70, 1910.
[4] Jour. Chem. Soc., 49, 74, 1886.
[5] Jour. Soc. Chem. Ind., 11, 584, 1892.
[6] Ber., 33, 2265, 1900.
[7] The Inst. of Petroleum Technologists.
[8] Jour. Franklin Inst., 180, 653, 1915.
[9] Loc. Cit.

tenths of a cubic centimeter, one cc. of 95.0 per cent sulphuric acid was added from a burette. The bottle was shaken for five minutes, cooling at the same time in order to avoid heating. Following the same procedure, two, three and four cc. of acid were added. The bottle was centrifuged for three minutes, enough sulphuric acid added to bring the unabsorbed oil upon the scale on the neck and the bottle again centrifuged until no further increase of unabsorbed oil was obtained. The reading of the amount of unabsorbed oil was made, and the unsaturated formation was found by difference.

No extreme accuracy is claimed for the method. It is well recognized that the determination of certain hydrocarbons is beset with particular difficulties because the chemicals used overlap other groups to a greater or lesser extent. In this particular case, the concentrated sulphuric acid, by means of which the unsaturated hydrocarbons were determined, attacks the low boiling aromatics, the naphthalenes and even the paraffins. For this reason, the method does not lay claim to any great accuracy. All that is claimed is that the method was of sufficient accuracy to bring out in unmistakable terms the effect of temperature on the unsaturated formation.

The first determination for unsaturation was made on the oil used for the cracking experiments. Concentrated sulphuric acid did not have any effect upon it.

The determination of the unsaturated compounds in the cuts was simple to make, although great care had to be taken with the determinations of the lower boiling fractions. The addition of even a small quantity of sulphuric acid produced great heat. For this reason, the oil was cooled before the addition, and immediately held in running cold water to avoid heating. The acid produced a black red sludge, the depth of color of which depended on the amount of unsaturated compounds present.

The experimental results obtained are all based on the determinations in the different cuts. From these data it was possible to bring out the following, which are shown in tables and in figures:

1. The effect of temperature on the per cent of unsaturation in the cuts to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C. and 270 deg. C. to tar.

2. The effect of temperature on the per cent of unsaturation in the gasoline cut to 150 deg. C.

3. The effect of temperature on the percentage of unsaturated compounds in the recovered oil in the cuts to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C., 170 to 230 deg. C., 230 to 270 deg. C. and 270 deg. C. to tar.

TABLE 1—PERCENT OF UNSATURATED COMPOUNDS IN THE DISTILLATION CUTS

Temp. (degrees C)	450	500	550	600	650	700	750	800
Per Cent Unstd. Cmpds.								
0 to 95	36	40	51	50	39	29	19	5
95 to 120	..	38	39	33	21	18	7	4
120 to 150	20	28	35	52	29	33	10	..
170 to 230	..	..	11	15	17	20	..	..
230 to 270	1	4	6	8	10	16	..	..
270 to tar	1	2	2	5	9	20	..	..

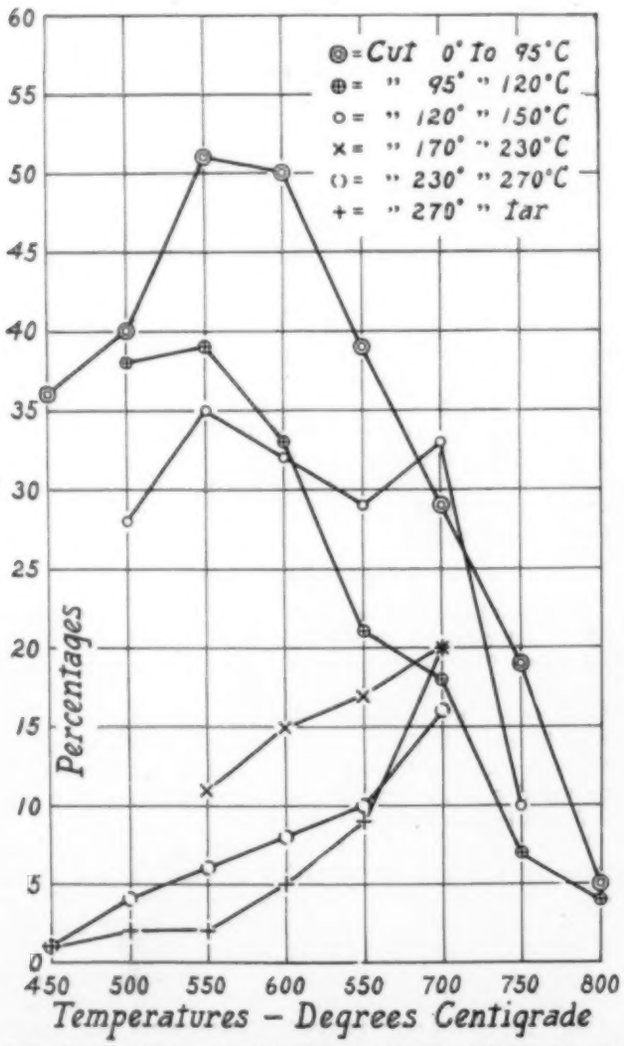

FIG. 1—PER CENT OF UNSATURATED COMPOUNDS IN DISTILLATION CUTS TO 95 DEG. C., 95 DEG. TO 120 DEG. C., 120 DEG. TO 150 DEG. C., 170 DEG. TO 230 DEG. C., 230 DEG. TO 270 DEG. C., 270 DEG. TO TAR

Discussion of Experimental Results

A. THE EFFECT OF TEMPERATURE ON THE FORMATION OF UNSATURATED COMPOUNDS IN THE CUTS TO 95 DEG. C., 95 TO 120 DEG. C., 120 TO 150 DEG. C., 170 TO 230 DEG. C., 230 TO 270 DEG. C. AND 270 DEG. C. TO TAR

It must be borne in mind that the original oil which was cracked boiled between 250 and 350 deg. C., and was not attacked at all by sulphuric acid. Decomposition by heat produced low boiling fractions and changed the original fraction. This amount of decomposition was proportional to the temperature employed.

Fig. 1 brings out the decomposition to low and high boiling unsaturated hydrocarbons. The data should be divided into two parts, (a) the per cent of unsaturated compounds in the cuts up to 150 deg. C., and (b) the per cent of unsaturated hydrocarbons in the cuts from 170 deg. C. to tar. Each set has its characteristics. In the cut below 150 deg. C., the per cent of unsaturation reached a maximum at 600 deg. C. in all three cases, and then decreased to practically zero at 800 deg. C. In the cuts above 150 deg. C., the amount of olefins and similar compounds attacked by sulphuric acid increased with temperature. The determinations could not be made at the two upper temperatures 750 and 800 deg. C. as these cuts consist almost entirely of the solid aromatics, naphthalene and anthracene. It is considered that a similar maximum would have been obtained provided these could have been made, and that the unsaturation would have decreased at 800 deg. C.

These data may be used to show the effect of temperature on the formation of unsaturated compounds such as olefins, and more especially the course of the cracking reaction. The original high boiling oil on thermolization splits to lower boiling fractions containing paraffins, naphthenes, olefins and aromatics with the production of the latter depending on the conditions. In the low boiling fractions at the low temperatures, one only expects to find paraffins, naphthenes and unsaturated compounds. From the data, it appears that the

amounts of saturated compounds such as paraffins and naphthenes at 450 and 500 deg. C. predominate in the cut to 95, and likewise in the other two low boiling cuts. Increasing the temperature of the reaction increased the percentage of olefins in each cut. This was acompanied by increased formation of aromatic compounds[10], and hence the paraffin and naphthene content must have decreased. At the higher temperatures, olefins and alephatic saturation decreased, and aromatic compounds predominated in each cut.

The course of the reaction with temperature of the decomposition to low-boiling products may be represented by

High-boiling paraffins →
Low-boiling paraffins →
Low-boiling unsaturated hydrocarbons →
Low-boiling aromatics.

Besides cracking the starting oil to low-boiling fraction, the reaction has also changed the character of the oil, and as the heat effect increases the amount of unsaturation increases, although it is not so large as was found in the lower boiling fractions. These facts are brought out from the degree of unsaturation in the high-boiling fractions, 170 deg. C. to tar. While the data do not show, it is to be expected that this formation would also reach a maximum and then decrease with the resulting formation entirely of naphthalene and anthracene in these cuts. The change with temperature on the character and composition of the high-boiling cuts may be expressed as

High-boiling paraffins →
High-boiling unsaturated compounds →
High-boiling aromatics.

B. THE EFFECT OF TEMPERATURE ON THE PERCENTAGE OF UNSATURATED COMPOUNDS IN THE GASOLINE CUT TO 150 DEG. C.

The total percentage of the unsaturated compounds in the gasoline cut was found by combining the percentages in the cuts which made up the fraction to 95 deg. C., 95 to 120 deg. C., 120 to 150 deg. C. For 450 and 500 deg. C. an estimation had to be made, since values were not obtained for the cut 95 deg. to 120 deg. C. at 450 deg. C., and 120 to 150 deg. C. at 800 deg. C. The results are similar to these in the distillation cuts which make up the fraction. The unsaturation, represented by 28.0 per cent at 450 deg. C., reached a maximum of 44.0 per cent at 550 deg. C., and declined to practically zero at 800 deg. C., the value being only 5.0 per cent.

Aside from bringing out the successive steps of the reaction resulting in the formation of the lower boiling hydrocarbons, the data are interesting in their relation to the making of gasoline by cracking of petroleum at atmospheric pressure. From the amount of unsaturation formed, it would not be advisable to crack an oil similar to the one employed in these experiments for gasoline, due to the high degree of unsaturation in the gasoline obtained. The refining losses, represented by the percentage of unsaturated compounds, would be excessively heavy, and enough to make a commercial operation prohibitive at atmospheric pressure. Although at higher temperatures the amount is small, it is due to the large percentage of aromatic compounds, benzene, toluene and xylenes, which have been formed, and which would not be used for gasoline at the present time.

If the effect of temperature in the cracking of oil in the gas phase may be compared to the effect of pressure in the cracking in the liquid gas phase, it would appear that the data from the Burton process and the results obtained by Brooks[11] are similar to those found in the present research. The decrease in unsaturated products in which increased pressure found by them corresponds to the decreased formation with increased temperature in the present case after the maximum has been reached. There arises the interesting possibility that increased pressure in the liquid gas reaction, besides cutting down the olefin formation, produced aromatic compounds such as benzene, toluene and xylenes in the gasoline cut. There are no data to be had regarding this from the Burton process. Brooks, however, states that benzene, toluene and xylene were produced by distilling Oklahoma "reduced" oil under 100-lb. pressure, the same conditions which gave the minimum refining loss in the gasoline produced. This seems to bear out the assumption that decrease in olefin formation with increased presence is accompanied by increase of aromatics.

Some chemists may attribute the decrease as due to the polymerization of the olefins to naphthenes, as has been shown by Engler[12]. On the other hand, naphthenes decompose very readily to aromatic compounds by dehydrogenation, a fact which has been shown by Zelinsky[13] and others. The decrease in olefin formation may then be accounted for in two ways, which in both cases give the same end products: polymerization of the olefins to naphthenes, which in turn go to aromatics; polymerization of the olefins directly to aromatics.

[10] Loc. Cit.
[11] Loc. Cit.
[12] Ber. 42, 4610 (1909).
[13] Ber. 44, 3121 (1911).
[14] Loc. Cit.

TABLE 2—PER CENT OF UNSATURATED COMPOUNDS IN THE GASOLINE CUT, 0 TO 150

Temp. (degrees C)	450	500	550	600	650	700	750	800
Per cent unstd. cmpds.	28	36	44	41	33	25	15	*5

*Estimated

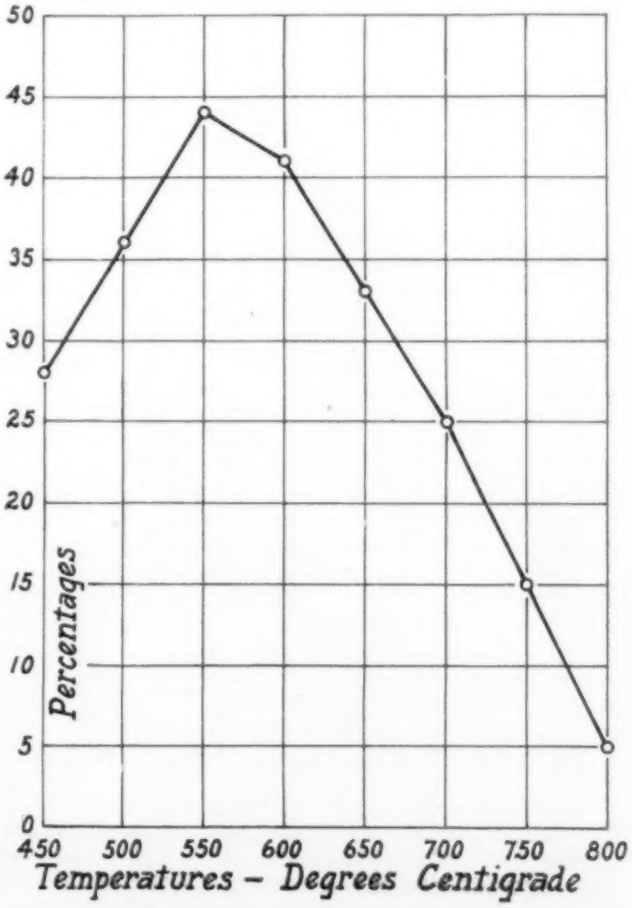

FIG. 2—PER CENT OF UNSATURATED COMPOUNDS IN THE GASOLINE CUTS TO 150 DEG. C.

It is difficult to interpret the general statement of Hall[4] that high temperatures make for high unsaturation, unless the general conditions of the cracking corresponding to those at 450 deg. C., beyond which point for 100 deg. saturation increases with temperature. Even under pressure, temperature decreases the olefin formation.

C. THE EFFECT OF TEMPERATURE ON THE UNSATURATED COMPOUNDS IN THE CRACKED OIL

Another combination gave the percentage of unsaturated compounds in the cracked oil, the data being given by distillation cuts.

As a general rule, the lower temperatures produced a cracked oil which contained the largest per cent of olefins in the lower boiling cuts. Moderately high temperatures resulted in cracked oils containing unsaturated compounds distributed through all cuts evenly. The highest temperatures gave but little in the lower boiling cuts, with indications that the same would be true of the higher boiling ones. It is regretted that data could not be obtained for these. It appears then that the cracked oil obtained by the thermal decomposition of a paraffin oil contains olefins, the amounts of which are governed by the temperature of the reaction. The formation with increase of temperature reaches a maximum, and then decreases to practically zero. Theoretically this is possible. At the higher temperatures, naphthalene and anthracene form the greater portion of the oil in addition to the pitch. These compounds are much more stable than any olefins known. And with the tendency of the reaction to produce aromatic compounds, it is not to be expected that there will be very much unsaturated formation in the cracked oils produced by the high temperatures, 750 and 800 deg. C.

TABLE 3—PER CENT OF UNSATURATED COMPOUNDS IN THE CRACKED OIL.

Temp. (degrees C).....	450	500	550	600	650	700	750	800
Per Cent Unstd. Cmpds.								
0 to 95	0.3	1.1	3.2	5.6	5.3	5.7	4.3	1.2
95 to 120	...	0.6	1.3	2.0	2.1	1.8	0.6	0.3
120 to 150	0.1	0.2	1.1	1.7	1.9	3.1	0.7	...
170 to 230	...	...	0.8	1.0	1.8	1.9	...	...
230 to 270	0.2	0.8	1.8	2.0	1.8	2.8	...	...
270 to tar	0.7	1.2	1.0	1.6	2.6	3.6	...	...

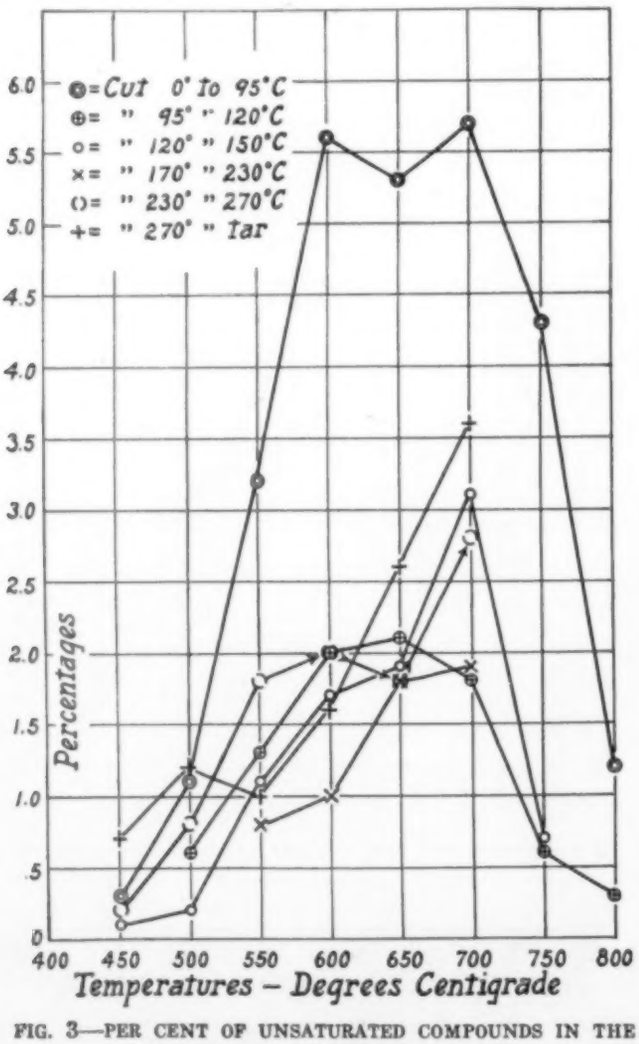

FIG. 3—PER CENT OF UNSATURATED COMPOUNDS IN THE CRACKED OIL BY DISTILLATION CUTS

Conclusions

From the experimental data it is possible to draw the following conclusions:

1. Unsaturated compounds are found in the recovered oils obtained by the cracking of a gas oil, boiling between 250 and 350 deg. C., and derived from Pennsylvania crude petroleum at atmospheric pressure, and at temperatures 450, 500, 550, 600, 650, 700, 750 and 800 deg. C.

2. With the temperature range employed, the unsaturation reaches a maximum in the lower boiling distillation cuts to 95 deg., 95 to 120 deg. C. and 120 to 150 deg. C.

3. In the higher boiling distillation cuts, the per cent of unsaturation increased with increase of temperature as far as data was obtained, with indications that a decrease would have been obtained at higher temperatures.

4. In the gasoline cuts, to 150 deg. C., the unsaturation reached a maximum and declined with increase of temperature.

5. In the cracked oils obtained, the total unsaturated formation increased with temperature with indications again that a decrease would have been found at the higher temperatures.

6. The change in the composition of the lower boiling fractions of the cracked oils with increase of temperature may be represented by low-boiling paraffins to low-boiling olefins to low-boiling aromatics.

7. The change in composition of the higher boiling fractions may be expressed with increase of temperature as follows: High-boiling paraffins to high-boiling olefins to high-boiling aromatics.

Pittsburgh Division, Aetna Chemical Co., Pittsburgh, Pa.

Announcement of Special Lectures at College of City of New York

The Department of Chemistry of the College of the City of New York, Dr. Chas. Baskerville, director, announces a series of very interesting spring lectures to be given at 3 p. m. at the college on the following dates.

March 10—Food control in New York City (illustrated), by LUCIUS P. BROWN, director Bureau of Food and Drugs, Department of Health, New York City.

March 17—The Extraction of Radium from Its Ores (moving pictures), by Dr. CHAS. L. PARSONS, U. S. Bureau of Mines.

April 7—Chemical Control of Medical Supplies Purchased for the U. S. Army, by Lieut. D. W. FETTEROLF, U. S. Army.

April 14—Science in the Humanities, by ELWOOD HENDRICK.

May 5—The Emancipation of American Chemical Industries (moving pictures), by Dr. THOS. H. NORTON, U. S. Department of Commerce.

May 12—Food Poison (illustrated), by JAMES P. ATKINSON, Department of Health, New York City.

Universal Flotation Theory*

BY C. TERRY DURELL

It seems incredible that every one of the many flotation processes are satisfactorily explained by an all-embracing theory. How can the theory of film flotation be identical with that of froth flotation? How is the theory of the Cattermole the same as that of the Callow? Thirty years ago Carrie J. Everson of Chicago described flotation as well as it can be described to-day, and it is quite evident from this description that thirty years ago a test might have been made for any of the many present-day processes using oil.

One theory will explain all processes of flotation if the essential element be the same in all cases. A process of elimination applied to each method of flotation will leave at least one essential element. This proved, there then follows the corollary that a theory that does not explain all processes of flotation satisfactorily is worse than useless as it is sure to confuse a subject already kept long in darkness by complicated litigation. Never before has litigation so retarded a science by smothering it in a cloud of secrecy. It is to be regretted that this condition has been brought about by some prominent engineers attempting to gain a world-wide control of all processes of flotation after the basic patents had expired.

The essential elements of flotation can be arrived at in two ways: (1) Investigation of conditions under which different minerals float; and (2) investigation of all different processes. In Australia, the home of flotation, more flotation experiments have been carried out than in any other country. This statement will not hold true for long judging from the present rate of advance in this country.

Kenneth A. Mickle's experiments published in the Proceedings of the Royal Society of Victoria[1] furnish the most complete record of systematic research to learn the reasons for flotation. These experiments were carried on with different metals and minerals in the laboratory and subject to the conditions met with in the several flotation processes. He tried them with water, oil, acid and alkali; hot and cold; at atmospheric and reduced pressure and in various combinations. Many of his experiments I have confirmed at the School of Mines. His experiments show that minerals at the surface or in the interior of liquids float or tend to float due to:

1. Liberation of gas contained in the liquid either by reduction of pressure or heat;
2. Generation of gas in the liquid by means of acid; or
3. Supersaturation of the liquid with gas.

He shows that minerals absorb (occlude) gas to a degree not previously suspected and that the effect of this occluded gas is that:

1. Particles are not wholly wetted by immersion in water;
2. Particles tend to float when sprinkled on a liquid surface;
3. Particles collect bubbles when heat or vacuum is applied; and
4. Particles collect bubbles evolved from a gas saturated solution.

The Swinburne and Rudorf[2] experiments show that "It seems necessary that the gas should be produced at the surface of the particles themselves." Many other references might be cited to show that the whole subject of flotation depends upon gas occlusion by the minerals to be floated.

As was to have been expected, Mickle showed the gas held by flotation concentrates consists almost entirely of nitrogen, oxygen and carbon dioxide. That is to say, the occluded gas was from the atmosphere.

These experiments have thus eliminated oil, acid, alkali, heat, vacuum, saturated gas solutions and the like as being essential elements of flotation. The conclusion that necessarily follows is that flotation depends on the fact that, due to the occluded gas of the mineral particles, they become entangled or caught by the surface film of: (1) the free surface of the liquid; or (2) the surface of a gas bubble; (a) above the surface or (b) under the surface.

It is well now to classify and investigate the different processes to see if a similar system of elimination will give the same results as this obtained from laboratory experiments.

Surface Tension Flotation

One of the oldest types of flotation is that which the prospector, in panning, tries to guard against. How easy it is to drain the water from the trail of fine gold in the pan and then pick it up on the surface of the water! Every vanner-man can testify as to the richness of concentrate from the settling boxes back under the machine behind the main concentrate box. This is the concentrate that dries as the belt travels down over the end of the vanner and floats on the surface as the belt dips into the water in the concentrate box. Hezekiah Bradford in his patent No. 345,951, in 1885, reverses this process by using a belt to remove the floating concentrate. It was nearly twenty years later (1904) that Macquisten used a spiral in a tube to lift and expose the pulp to the air so the metallic particles would float on the surface of the water in the tube. This was a commercial success, though oil is now used to aid the process. Henry E. Wood's machine, patented March 21, 1911 (No. 987,209), feeds dry ore gently onto the surface of water so that the metallic particles float over a lip and are saved. All of these cases come under what may be termed "surface tension flotation." Evidently the only essential feature is that the particles to be floated be exposed to air. That is, there must be a chance for gas occlusion. The selective action, which causes the metallic particles to float while the gangue particles sink, will be taken up later.

Bulk Oil Flotation

How "the virgins drew up gold by means of feathers daubed in pitch" is told by Herodotus. Thus that pitch, oil, grease and the like adhere to metallic particles with greater force than does water has long been known. This fact was first recognized in a patent (No. 488, British) to William Haynes in 1860. Under the Elmore patents of 1898 and 1901, bulk oil flotation was put on a commercial basis, although the many plants built in different parts of the world were doomed to failure because of the great quantities of oil necessary. Excessive oil is necessary, due to the little difference in specific gravity between oil and water as compared to the greater difference in specific gravity between water and the metallic concentrate. As no acid was at first used by the Elmore process, it is not an essential element to flotation.

The Cattermole patent in 1903 improves upon this by using less oil in what was known as the oil granule process. These granules were then removed in various ways either from the bottom of the container or driven to the surface by an upward current of water or gas. This was the forerunner of the present froth processes, but the only plant built was a complete failure. This

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*Excerpt from Colorado School of Mines Magazine, February, 1916.

[1]Vol. 23 and 24, Part 2, 1911. Abstracted in Eng. and Min. Jour., Aug. 12, 1911, and July 13, 1912.

[2]Faraday Society paper read Dec. 12, 1905. Abstracted Eng. and Min. Jour., February 10, 1906.

was to treat 400 tons daily at the Central Mine, Australia. Everyone who has made a froth flotation test has, probably, at some time, added too much oil and seen these granules resting above the pulp at the bottom of the vessel. Some may rise to the surface of the liquid and drop back again. In the Cattermole process, soap and acid were used, but a test, as above, shows that granules will form with oil only, so these two things are not essential elements. The only bulk oil flotation plant that I examined was at the Lake View Mine, Kalgoorlie, Australia. It, like all others, was a failure so I was not able to determine if gas occlusion by the metallic particles is the essential element to the process. From the very nature of the process, oil of course is an essential element. Mickle's experiments showed that mineral particles deprived of occluded gas do not, as a rule, become coated with oil in the presence of water. The selective action necesary for this flotation will be taken up later.

Froth Flotation

In taking up these processes in detail to eliminate all but essential elements to flotation, such questions as air froth or oil froth, selective or preferential flotation, and the like will not be discussed. These things as well as the forces, adhesion, electricity, cohesion, surface tension, etc., will be taken up under other headings later. About four years ago I made a trip to Australia and studied these processes quite carefully at the largest plants then in the world working four distinctly different methods. Since then I have seen several plants operating in this country but with only one different method or machine—the Callow.

Delprat Type.—The Delprat and Potter processes were developed independently at the same time, patented in 1902, and are practically the same. This was the first commercially successful froth flotation. It has since proved unfortunate for Minerals Separation that the Fremont patent in the same year was only taken out in Italy and England. For this reason it was necessarily suppressed by the purchasers. Also processes where gas is generated by electrolysis like the Fields come under this heading.

As G. D. Delprat was general manager of the Proprietary Company at Broken Hill, his process was naturally used there. About 1000 tons were being treated daily when I studied the flotation process at this property. A "push feeder" delivered 700 pounds of ore per minute to a single spitzkasten where flotation took place without agitation except that of the upward current of hot acid solution being added at the bottom. By heating the solution with superheated steam, it was intended to work with a solution as near 80 deg. C., the critical temperature for flotation, as possible. The working solution temperature, however, was below 70 deg. C. The quick action and simplicity of the process was most pronounced. A marketable zinc concentrate was being produced with high recovery without retreating it or the tailing. The essential elements may be summed up as follows: gas, acid and heat in addition to the ore and water. The acid attacking the carbonates in the ore produced the bubbles in addition to the selective action which will be taken up under a separate heading. This gas made the bubbles for the froth, as no air was taken into the solution in any way except the little that might come in with the ore. None could come in with the solution as no jet or nozzle was used above the surface of the liquid, which would have carried air in, as will afterward be described. This solution was brought in at the bottom of the spitzkasten and, being hot, could contain but little dissolved air. Since heat was necessary, its only function was to expel occluded air from the mineral particles the same as from liquid in accordance with the law of Henry.

Vacuum Type.—The Elmore vacuum machines were being used at the Broken Hill, British plant, although they had been thrown out from several other plants there. This was not due to unsuccessful operation but to litigation. No more than the following essential elements are necessary for the operation of the Elmore, the only successful vacuum process: vacuum (to liberate the air to form bubbles), acid, oil and alkali. Cast iron machines are used so lime is required to neutralize the pulp before it goes to the vacuum machines. The acid of course is not to generate bubbles as in the Delprat process. Therefore, the acid creates the selective action the same as in the Delprat process. In accordance with Henry's law, gas or air is liberated from the pulp by reduction of pressure to form the froth. As will be shown later, these bubbles must necessarily form on mineral particles as nuclei. The bubbles burst very readily in the Delprat process, but there is such an ebullition that any metallic particles thus dropped are caught by the bubbles below. There is no chance for this with the Elmore so the bubbles must necessarily be more persistent. In the Delprat, the bubbles are armored with the metallic particles. To make them more persistent in the Elmore, oil, in addition to the metallic particles, is used to coat them. This toughening of the froth with oil will be taken up under a separate heading.

Minerals Separation Type.—Under this heading may be grouped all processes or machines using rapidly revolving paddles or stirrers to beat air into the solution. This method of forcing air into solution beyond the point of saturation was known long before our grandmothers used it to beat eggs or whip cream. It matters not whether air be beaten by being admitted to the suction of a centrifugal pump or to the periphery under pressure or beaten in by the propeller on the vertical shaft of a mineral separation or other machine. The essential elements can be eliminated as follows: air (beaten in to supersaturation), acid, oil and heat. What is the difference whether bubbles be formed from air coming out from a supersaturated solution or from a solution subjected to vacuum? Bubbles will form on mineral particles as nuclei in either case. The acid here of course acts as in the former case. Since heat is not always used, its only function can be to assist in expelling the air from the mineral particles. The froth from these machines is the most persistent. This is due to the greater amount of slime and the better agitation to oil-coat the metallic particles. Like butter in a churn, these fine metallic particles are coagulated by the violent agitation. The mineral particles are so well oiled that an exceedingly coherent armor for the bubbles is produced. The oil films of these bubbles are extremely thin like those of other processes. Iridescent colors indicate this. The surface tension effect of the oil is added to that of the water for further toughening the bubbles.

DeBavay Process.—This, at first, appears to be a purely surface tension process. As originally patented by DeBavay, it probably was, but, as now used by the Amalgamated Zinc, Ltd., of Broken Hill, it even has the bubbles, although all the large ones are liberated before flotation commences. The same principles apply here as in any froth flotation. The clean sand is thoroughly agitated in an acid solution, washed and then again agitated in steel tanks with water to which a fixed amount of an oil mixture (mostly kerosene) has been added. The agitators in these tanks are like ship propellers and as large. This gives thorough oiling to the particles. A montejus delivers the pulp to the top

series of four each DeBavay cones. The pulp is, therefore, surcharged with air due to this air pressure, since the air dissolved by the water varies directly as the pressure. Norris has patented (No. 864,856) the idea of thus surcharging a liquid with gas, but he delivers the surcharged liquid beneath the surface of the pulp mixture. The Callow machine also uses this principle except that the air pressure is exerted on the bottom of the liquid instead of on the top as with a montejus. There are no bubbles or froth because the pulp mixture from the montejus is turned on to the apex of the cones and spreads out, flowing down the steeply inclined surfaces. The essential elements to this process are: gas (in the form of air), acid and oil. These are the same as with preceding processes. Although there is no froth, air is here the prime requisite while the acid creates the selective action. The metallic particles are so well oiled they are not easily wetted by the water while their air films and minute attached bubbles bodily lift them to the surface of the water if, by chance, they go in under instead of on the surface when they strike the water at the periphery of the cones. In a laboratory test, the metallic particles seem to jump from the bottom of a beaker to the surface of the liquid.

Callow Type.—This includes all froth flotation processes depending on the supersaturation of the liquid by air pressure in accordance with the law of Henry. The DeBavay process was taken up previous to this as it is the connecting link between this and Mineral Separation type. It (DeBavay) uses violent agitation which beats in air and also direct air pressure which supersaturates the pulp mass.

This supersaturation is caused, according to the Norris patent, by subjecting the liquid to an air pressure of several atmospheres. In the Callow machine, it is "a hydraulic pressure varying from 15 to 40 inches" that causes the liquid at the bottom of the box to absorb air beyond the saturation point of the surface liquid at atmospheric pressure. If too much air is blown into a Callow machine, the effect is the same as the air in the pachuca tank—agitation.

The bubbles composing the froth are derived from that air which was first absorbed and afterward liberated on a mineral particle as a nucleus in the same way that air, beaten into solution in a Mineral Separation machine, supersaturates the liquid and comes out in the form of bubbles. A jet of air turned into liquid pulp produces bubbles which effect no mineral attachment. They pass through the pulp as do those from excess air in the Callow cell. The essential elements for the Callow type may be picked out as follows: air (from supersaturation of the liquid), oil and acid or alkali. The oil, as shown above, aids in making a more persistent froth. It is mixed with the pulp previous to entering the machine. The acid or alkali is to form an electrolyte for selective action.

Liquid Jet Type.—Heretofore only two ways of getting air into solution have been taken advantage of to aid flotation. These, as mentioned above, are: (1) beating it in as is done in Mineral Separation type; and (2) surcharging the liquid with gas as is done in the Callow type. While experimenting at the Colorado School of Mines some three year ago, I developed a third way which is now being patented. One of the patents has been issued.

Common occurrences of this phenomenon are seen everywhere. On drawing water into a beaker, bubbles form and rise to the surface. Where does the air come from? A muddy overflow is caused in a settling tank by allowing the mill stream to be turned down into the tank from some little distance above. Froth forms and overflows. Hydraulic air compressors and blowers are operated on this principle by turning a stream of water down a shaft or pipe. In the same way that an air film surrounds a drop of liquid so that the drop method may be used in determinations of surface tension, so does an air cylinder enclose a liquid jet. This adhesion is so great that air is carried into the liquid to the supersaturation point and it comes out in the form of bubbles.

The model I built at the School treated ore at the rate of twenty-five pounds an hour working in an acid solution with oil fed to the first cone. This type of machine produces either a scum float like DeBavay's or a thick persistent froth with well armored bubbles. The essential elements may be noted as follows: air (brought in by the liquid jets), oil and acid, or alkali.

Having classified flotation into that of (1) Surface Tension, (2) Bulk Oil and (3) Froth and subdivided Froth Flotation into the different types of (a) Delprat, (b) Vacuum, (c) Mineral Separation, (d) Callow, and (e) Liquid Jet, there are found only these few essential elements as follows: air or other gas, acid, heat, vacuum, oil and alkali. These only are necessary in addition to the liquid and the ore. It is possible to still further eliminate.

Essential Elements

Cold solutions were seen to be used with some processes. Therefore heat is not an essential element to flotation. Vacuum is used in the one type to produce the gas so it is not essential to flotation. Oil is not always used in froth flotation so it is not an essential element to any except bulk oil flotation. This fact is also shown by the new process of Louis A. Wood. An alkali is used in one case to neutralize the excess acid and in others in place of an acid. Either an acid or an alkaline solution will do and, from the amounts used in mill solution, it is seen that extremely dilute solutions are effective. That is, complete ionization exists and the effect is that of an electrolyte. By this process of elimination there is left the essential elements as follows: air for surface tension flotation; oil for bulk oil flotation; and gas and an electrolyte for froth flotation.

It is seen that the gas, to form bubbles in froth flotation, can be generated chemically or electrolytically within the pulp mass or it can be (1) beaten in with stirrers, (2) forced in by pressure (that of the atmosphere or greater), or (3) carried in by jets. Something more than mere bubbles of gas within the pulp mass is necessary to make froth flotation effective.

The mineral particles must either be attached to the bubbles or the bubbles must be attached to the mineral particles. It amounts to the same thing whether the bubble be attached to the solid or the solid attached to the bubble. Since a bubble carries with it a surface film of liquid, the mineral particle must be caught by this surface film in froth flotation or caught by the free surface of the liquid in surface tension flotation. The necessary conclusion then is that some inherent property of the mineral particle itself is the cause of its resting on the surface of the liquid in the one case or on the surface of the bubble in the other. If it were possible to attach a mineral particle to a bubble already formed by some physical, chemical or electrical force, then it might be possible that surface tension flotation and froth flotation are in no way related, and that bubble attachment is in no way dependent upon some property of the particle itself. It is a well known fact, however, that no such attachment can take place to bubbles that are already formed.

A stream of compressed air turned into a pulp mass in a perfect float condition can not effect flotation, as

is well known by every one who has tried it. The bubbles not only rebound from one another but the mineral particles show no tendency to adhere and the bubbles come to the surface without the mineral particles. This is due to the surface film, which phenomenon will be taken up later, when it will be shown that there can be no adhesion between this liquid film and the mineral particle, be it either wetted with oil or water. There is no reason for any chemical affinity.

Electrical Theory Insufficient

In an electrical field, it is possible for bubbles to be electro-negatively or electro-positively charged. There is no reason why these charges might not be reversed at will by varying the field. Also it is a well known fact that mineral particles can be electrically charged and this is taken advantage of in electrostatic concentration, Cottrell dust precipitation, clay separation, etc. It is also shown in colloidal work that, under the same condition, some minerals are negatively charged while others have an opposite charge. It is upon these facts that electrical theories of flotation are based. Assume that the particles of metals, sulphides, tellurides, arsenides and the like "have charges of one polarity (positive), and that non-floatable particles have charges of the opposite polarity (negative)," and also that the bubbles are negatively charged. Witness, then, the metallic particles jumping for and clinging to the bubbles. A beautiful theory if it were true and would explain all connected with flotation.

In the first place, flotation is not dependent upon an electrical field as is electrostatic concentration, dust precipitation, Botho Schwerin's electro-osmotic process and others. It would also be possible to attach mineral particles to bubbles already formed by the assumption of an electrical theory. So far, these electrical theories have considered oil as an essential element to flotation, which, as shown above, is not the fact. If a slight change in the strength of the electrolyte will change the polarity of quartz, calcite and the like so as to cause them to sink, when before they were floating, why will it not also change the polarity of some metallic particles so as to create a preferential flotation? No. It is far better to make a theory conformable to the facts than to try to ignore and twist facts to conform to some of the present electrical theories. Since there is no known way to attach mineral particles to bubbles already formed, bubble attachment depends directly upon some property of the particle itself. This property must then be the same for particles floating in either a surface tension or a frothing machine. As shown by Mickle's experiments, this must be due to gas occlusion.

Why is it then that no solid can be floated unless it contains occluded gas? A particle once wetted with the flotation liquid tends to sink as there is no surface tension effect tending to float it. Water is always used as the flotation liquid as it is the cheapest and has the greatest surface tension of all liquids except mercury. If all gases be driven from a solid, water will enter the pores and adhere to its surface. No surface tension effect can be then exhibited towards it for the reason that it is then as part of the water. Thus a force of adhesion predominating, flotation can not take place. This truth is not so readily seen when the particle is below the surface of the water and an attempt is made to float it by means of a bubble. The surface tension of the liquid film surrounding a gas bubble is much greater than the adhesive force of the gas for a solid. The gas is, in this way, firmly held within the enclosing liquid film and attachment between it and a solid cannot take place. As has been shown above, it is only the gas that comes into being within the pulp mass that is of any value in flotation. In other words, this nascent gas is attracted by the gas at the surface of the solid. A cohesive force exists between the molecules of the gas at the surface of the solid and those in the immediately surrounding liquid so that the solid becomes a nucleus for the formation of a bubble from the nascent gas of the liquid. As shown above, there are three mechanical ways of forcing air or a gas into solution. Also there are three methods of expelling it: (1) supersaturation so that the excess gas is driven out; (2) heating to increase the volume and drive some out; and (3) reduction of pressure.

Role of Occluded Gases

The same cause that tends to supersaturate a liquid with gas will evidently tend to supersaturate a solid with this same gas if this solid be within the liquid. Also the dissolved gas will evidently be expelled from both the liquid and a solid within it by the same force—one of the above. Due to adhesion, the gas, as it is expelled, tends to condense on the solid or increase the amount of absorbed gas. Lest confusion arise, it may be stated that "absorb" is here used in the sense of being one of the three ways that solids hold gases. With sufficient condensation, a bubble will form on the surface of the solid from these molecules as they collect.

As a logical sequence from the above reasoning, solids with high occlusive power for gases should have a greater tendency to float. Hezekiah Bradford was the first to recognize this fact.[1] "These floating particles appear to possess some peculiar qualities which repel water from their surfaces, especially when the particles are exposed, even momentarily, to atmospheric air." It is only necessary to look into the subject of ore deposition to learn the reason why metallic particles occlude gas more readily than other minerals. Chemical affinity assists in this occlusion of air and carbon dioxide, which eventually change the sulphides and like ores into sulphates, carbonates, oxides, etc. This greater power of occlusion is a cause of selective flotation.

Selective flotation is here used as a general term in contradistinction to preferential flotation, an accepted term to designate the separation of minerals that ordinarily float together. Horwood accomplishes this by a roast that oxidizes some sulphides and not others. The same effect is accomplished by others by coating the sulphides not desired in the concentrate. Leslie Bradford uses a reducing gas to accomplish this result.

By the aid of the microscope, Hebron, an associate of Carrie J. Everson, discovered that the desirable minerals, to be saved by concentration, have larger pores and surfaces than equal sized gangue particles. This gives greater chance for gas occlusion. Oil and like substances are usually but slightly soluble in water. The reverse is also true. There is little adhesion between water and a surface wetted with oil, or oil and a surface wetted with water. Oil, due to its property of capillary attraction, can readily enter the pores of solids not filled with water. Therefore, most metals, sulphides and the like containing occluded air, are capable of absorbing more oil due to their larger pores and surfaces. With sufficient oil thus attached, agglomeration or bulk oil flotation takes place.

By this process of elimination, the same conclusion is reached as that demonstrated by Mickle's experiments. Gas is the necessary element for surface tension, bulk oil and froth flotation methods and this must be occluded gas. Nascent gas and an electrolyte are also essential elements for froth flotation.

[1] U. S. Pat. No. 345,951. 1885.

Function of Electrolytes

What is the function of the electrolyte? As has been shown, an acid or an alkali creates the selective action in froth flotation. How? By its ability to vary the contact angle between the surface of the mineral particle and the liquid film on either a bubble of measurable radius or a horizontal liquid surface of infinite radius. Dr. Young showed the constancy of contact angles. H. Livingston Sulman, investigating figures for contact angles found "discrepant readings" due to "existence of a variable range of the contact angle." C. G. Lamb termed this angular difference "the angle of hysteresis." Speaking of this, Mr. Sulman says:[4] "Whereas the angular hysteresis of silica in plain water may exceed 30 deg., thus indicating the substance to have a definite power to occlude gas and to float, it drops from 4 deg. to nil in water acidulated with sulphuric acid."

The occluded gas can be driven out from a solid in the same way that it can be driven from a liquid. This gas of the solid particles will cause them to become nuclei for the formation of bubbles from the gas "coming into being" from the liquid and, as the bubbles grow, the particles are lifted or floated. Since there is more occluded gas in the metallic particles, all that is necessary to create the selective action of flotation is to drive out a considerable portion of the occluded gas from all particles. There then will be insufficient gas remaining with the gangue particles to cause them to act as nuclei upon which to grow bubbles. The metallic particles still having occluded gas are then floated while the gangue particles sink.

As above shown, this selective effect is produced in extremely dilute solutions. An electrolyte produces it, but how? It was also shown that some force is required to expel occluded gas. No outside force such as pressure or heat is the cause. Therefore it is an internal one that drives this occluded gas from the mineral particles. The ions of the electrolyte displace the equilibrium and the force that causes the gas occlusion is, at least partially, neutralized so that the tendency of the gas is then to diffuse throughout the liquid instead of remaining in the solid.

Effect of Osmosis

A parallel case in physics is osmosis. The function of the electrolyte, therefore, is to create osmotic pressure. The septum is the surface of the mineral particle. Ions of the electrolyte enter the solid while those of the gas leave. This action continues to the eutectic point and bubbles form on the metallic particles, as described above. Greater delicacy of manipulation is obtained with an alkali. Further advancement along this line means that selective action can be created between sulphates, carbonates, etc., and gangue minerals. Also that, by means of a variation of the electrolyte, preferential flotation can be effected and different metals can be separated.

Increased strength of the electrolyte will sometimes "kill" the float; or, in other words, increased osmotic pressure drives the air from the metallic particles leaving them in the same condition as those of the gangue. This effect is not to be confused with an entirely different phenomenon which produces the same effect. Colloidal impurities like tannin, saponin, etc., or volatile oils and the like destroy bubbles by reducing the surface tension to the extent that the gas pressure from within bursts them. This weakening of the surface tension by a colloid is thus seen to be entirely different from the strengthening of osmotic pressure by a crystalloid although the result is practically the same—no froth.

[4]Presidential address of H. Livingston Sulman. Institution of Mining and Metallurgy Transactions, 1912.

In studying this selective action, it is difficult to explain the motive power of osmosis, as present authorities do not agree. According to the Van't Hoff school it is the kinetic energy of the dissolved molecules obeying the laws governing gas presure. It is the impact of these molecules against the walls of the semi-permeable membrane. On the other hand, Kahlenberg shows it to be the force of chemical affinity, while Professor Traube proves it is an "interfacial pressure obtained by subtracting the surface tension of one fluid from the tension of the fluid into which it diffuses." Since surface tension is a cohesive force, osmosis may depend upon electromotive force because, according to both Sir Oliver Lodge[5] and Fernando Sanford,[6] the forces of chemical affinity and cohesion are electrical. This is a much mooted question for, by assuming Dr. Lupke's[7] "Osmotic Theory of the Current of Galvanic Cells," the starting point is again reached. Fortunately the question as to the motive power of osmosis has no bearing on the result of the selective action in flotation caused by osmosis. As shown, this selective action in all three methods of flotation depends primarily upon gas occlusion by the mineral to be floated. Mickle showed that no mineral will float on the surface of hot acid solution, even if dilute. Thus an electrolyte creates a greater selective action in surface tension flotation.

This selective tendency exists in neutral solutions due to the fact, that metallic particles occlude more gas than others. In bulk oil flotation, the metallic particles have occluded more air and, hence, are more easily wetted with oil than with water. The osmotic force set up by the electrolyte in froth flotation expels occluded gas from the mineral particles. There is still left with the metallic particles sufficient gas for them to act as nuclei so that the nascent gas of the liquid may form bubbles to float them.

Just as vapor must have a nucleus upon which to form a rain drop, so the nascent gas in flotation pulp must have a nucleus upon which to form a bubble. Duhem[8] shows that a bubble will never form where the liquid is continuous, due to the fact that its infinitely small radius would be less than the limiting radius of collapsibility. Note how the vapor bubbles of boiling water form on the bottom or sides of the vessel.

Action of Bubbles

Not only are bubbles necessary for froth, but they must be more or less persistent. The surface film that encloses the bubble as it is formed in the interior of the liquid becomes a part of that bubble and, due to surface tension, remains with it throughout its pasage to the surface of the liquid, in the same way that the surface film of a soap bubble remains with it throughout its passage in the air. This is easily proved by slowly blowing a colored bubble at the bottom of a large beaker of which the upper portion at least is filled with clear liquid. Due to this fact, the bubbles may have their films strengthened or toughened so they will endure for a longer time. Therefore, if the bubble be coated with some such substance as oil, the total force of surface tension is increased, due to the surface tension of the water film plus that of the oil film. Surface tension tends to decrease the size of the bubble as is well illustrated by Boys,[9] while the expansive force of the gas enclosed tends to enlarge it. The hydrostatic head aids surface tension in maintaining the bubble in the interior of the liquid.

[5]Electrons by Sir Oliver Lodge, Principal the University of Birmingham; Chap. 16, Nature of Cohesion, Page 153, July, 1906.
[6]A Physical Theory of Electrification (1911), by Fernando Sanford, Prof. of Physics, Stanford University. Page 43.
[7]Elements of Electro Chemistry, by Dr. Robert Lupke. Part 3.
[8]Thermodynamics and Chemistry, by P. Duhem, 1903. Page 366.
[9]Soap Bubbles, by C. V. Boys.

Arriving at the surface, the bubble may burst due to: (1) interior gas expansion; (2) adhesive force of the contained gas for the atmosphere; (3) evaporation of the enclosing film. Therefore an immiscible substance aids in two ways in making the bubble more persistent: (1) adding to the force of surface tension; (2) forming a film less easily evaporated. Since molecular forces are dealt with, these films approach one molecule in thickness and hence little oil is required. The colors of the bubbles also show this.

In addition to the oil film, the bubbles may be still further strengthened by an armor of metallic particles. These metallic particles containing occluded gas are, as shown above, more easily oil-coated than gangue particles. Due to cohesion, an electrical force, these particles are firmly held together and to the bubble film, which is then enclosed in a network of them just as a balloon is enclosed in a netting of rope. Bubbles thus made will endure for days and have been spoken of as "oil froth."

Oils that are good "collectors" are practically insoluble in water and form a film not easily evaporated, so make persistent bubbles. Good "frothers" are oils more or less soluble and, while they make quantities of bubbles and much froth, evaporate quickly, so that the bubbles burst more readily. Mineral particles are very easily coated with volatile oils and the bubbles are readily armored, but they burst readily, sometimes with violence. Being soluble, these oils decrease the surface tension since their surface tension is less than that of water.

Most oils aid flotation in three ways: by (1) increasing surface tension of the oil film with the additional force of surface tension of the water film; (2) decreasing adhesive force of the water for metallic particles by forming films around them; and (3) increasing cohesive force of metallic particles for each other by means of the oil film. Thus it is seen that although oil is a great aid, there can be no universal theory for flotation which considers oil necessary. By this method of elimination, it is shown that all processes and kinds of flotation can be satisfactorily explained by gas occlusion and that the bubbles for froth formation are from nascent gas.

Imperial Reduction Co., Pasadena, Cal.

Coal, Coke and Limestone Efficiency in Blast Furnace Operation

BY BIRGER F. BURMAN

(*Concluded from page* 140)

Limestone Efficiency

Limestone is of a strong basic composition, while alumina must be considered as a distinct acid. Before limestone can act as a flux on other materials its own impurities must be satisfied by part of its own bases. Therefore the value of a limestone is dependent on the amount of its net available base.

A pure limestone contains 100 per cent carbonates, representing the maximum amount any limestone can contain. Consequently such a limestone must be considered as "100 per cent efficient" and another limestone with less carbonates as less efficient.

Phosphorus, except in very small quantities, must not be present; therefore, a limestone, even very efficient otherwise but containing comparatively much phosphorus, must be eliminated at the quarry.

Sulphur, on the other hand, may be taken care of by the furnace slag. However, it increases the cost of production. Therefore it should come within the scope of the regulating guide of an efficiency system. Under ordinary conditions the quantity of slag in the furnace is more than sufficient to keep this sulphur in a safe solution, but when it is remembered that its presence increases the already too high amount in the coke, it is evident that it will be of advantage to keep the amount of sulphur in limestone at its minimum.

The actual weights and not the oxygen shall determine the value of each part, whether base or acid in the matter of fluxing; and for the sake of further simplicity Al_2O_3 shall be considered equal to SiO_2 as acid and MgO equal to CaO as base. Other bases present as, for instance, FeO, shall ordinarily not be included with CaO and MgO when determining the efficiency, neither shall sulphur as CaS. In other words, in order to make as little work as possible for the chemist, analyses on SiO_2 and Al_2O_3 only shall be made on every limestone shipment at the quarry and on the daily consumption at the blast furnace. The difference between 100 and the summated acid, thus found, shall be considered as summated carbonate. For instance, a limestone containing

SiO_2	6.72 per cent
Al_2O_3	4.07 per cent
Total	10.79 per cent summated acid

will therefore have 100 — 10.79 = 89.21 per cent summated carbonate. If the slag runs with summated acid equal to summated base, the weight of useless stone must be 2 (summated acid) plus the weight of that carbonic oxide, which accompanies the base of the same weight as the summated acid. In this case the useless part of the limestone, considering CaO, CO_2 as flux, will therefore be $10.79 + (1.79 \times 10.79) = 30.10$ per cent, and the efficiency about 69.90 per cent.

Above calculations will be close enough for everyday use in order to simplify work in the laboratory. However, at the end of the week a complete analysis is made of an average sample of all the limestone consumed during the week. Based on this analysis a more thorough record is made. FeO as base is now included in the summated base and P_2O_5 and CaS are given due consideration.

LIMESTONE AT THE QUARRY

It is, of course, at the quarry that the quality of the limestone must be kept up or improved upon by the elimination of impurities. This can be done only by the aid of the laboratory. Analyses are made on average samples, taken on every shipment, sent to the blast furnace, and with the shipment the following report is forwarded:

REPORT ON LIMESTONE SHIPMENT NO.

Date of shipment:
Number of cars:
Weight of limestone (in tons of 2240 pounds): tons.
Kind of limestone:
Analysis: SiO_2 7.70%
Al_2O_3 4.58% 12.28%
P .01%
S .15%
Stone efficiency: $100-[12.28+(1.79\times12.28)]=65.74\%$

LIMESTONE AT THE BLAST FURNACE

There might be established such conditions at the quarry and the blast furnace that resampling and check analyzing would be unnecessary. However, that would be exceptional. It is safe to say that all limestone used at the blast furnace must be sampled and analyzed daily.

METHODS OF TAKING AVERAGE SAMPLE

All limestone used each day is sampled as usual. A certain weight of this sample, crushed and prepared, is put aside. The amount is a fixed weight per 1000 lb. of limestone used. At the end of the week the seven samples thus received are thoroughly mixed.

METHODS OF REPORTING ANALYSES

Daily form:

DAILY ANALYSIS NO. OF LIMESTONE

Used in the blast furnace No. Date:
Weight (in tons of 2240 pounds): Tons
Kind of limestone:

SiO_2	%	
Al_2O_3	%	%
P		%
S		%

Weekly form:

AVERAGE ANALYSIS NO. OF LIMESTONE

Used in the blast furnace No. during the week ending:
Daily samples used: No. thoroughly mixed.
Weight (in tons of 2240 pounds): Tons.
Kind of limestone:

SiO_2	5.80 %	Summated acid = 9.80%
Al_2O_3	4.00 %	
CaO	46.54 %	
MgO	2.78 %	Summated base = 50.21%
FeO	.89 %	Fe .69%
MnO		
P_2O_5	.023%	P .01%
CaS	.340%	S .15%
CO_2	36.57 %	in combination CaO, CO_2
CO_2	3.06 %	in combination, MgO, CO_2
Total	100 003%	

NOTE:

P_2O_5	equals $2.29 \times P$
CaS	equals $2.25 \times S$
CaO from which Ca in CaS has been reduced	equals $1.75 \times S$
CO_2	equals $\frac{11 \times CaO}{14}$
CO_2	equals 1.1 MgO

RELATIVE VALUE OF LIMESTONE

As was said under coke regarding the necessity of figuring out the relative value of that material, this can also be said of limestone. Standards are necessary for comparison, and averages for some previous period, say one year, should be adopted. Figures given below are merely inserted as examples and should be modified to suit local conditions.

STANDARDS:

1. Cost of coke per ton of 2000 pounds, here assumed to be $2.20
2. * Cost of pure available carbon (sulphur included), here assumed to be 4.701
3. Cost of limestone per ton of 2240 pounds, here assumed to be 1.10
4. Cost of slag from tapping to its disposal by the R. R., per ton of 2240 pounds, here assumed to be 0.20
5. Amount of pure fixed carbon to melt the slag: = 0.228 pound per pound of slag.
6. Acids / bases in the slag. Here assumed to be 1.
7. Actual weights and not oxygen proportions shall be considered as fluxing standards.
8. Al_2O_3 shall be considered as acid.
9. CaS shall be considered as neutral.
10. Analyses of coke and coke ash—here assumed (see below).
11. Maximum amount of sulphur in the slag—here assumed to be 1.40%.
12. The relative value of any limestone shall be determined by the cos per ton of 2240 pounds of pure available base.
13. It is assumed that coke ash and slag from flux go unchanged into the furnace slag.

EXAMPLE:

A certain limestone gives the following analysis:

SiO_2	5.80%	9.80% acids
Al_2O_3	4. %	
CaO	46.54 %	50.21% bases
MgO	2.78 %	
FeO	.89 %	
P_2O_5	.023%	P .01%
CaS	.340%	S .15%
CO_2	39.63 %	
Total	100.003%	

*This is a matter of course.—See Coke Efficiency.
Going to the slag: $9.80 + 50.21 + 0.34 = 60.35$

Standard analysis of coke (wet) used:

Moisture	2.50 %		SiO_2	6.02 %	
Vol. matter	1.56 %		Al_2O_3	3.61 %	
Fixed carbon	82.52 %		CaO	.666%	
Ash	12.53 %		MgO	.24 %	
P (remaining in the ash)	.024%	12.684%	FeO	1.80 %	
S (remaining in the ash)	.130%		P_2O_5	.055%	P = .024%
S (remaining in the combustibles)	.750%	.88%	CaS	.293%	S = .130%
			Total	12.684%	

Going to the slag: $12.684 - 0.055 = 12.629$

Limestone:			Going to the slag:	
SiO_2	5.80 %		5.80	
Al_2O_3	4. %		4.	9.80 acids
CaO	46.54 %		46.54	
MgO	2.78 %		2.78	
FeO	.89 %		.89	50.21 bases
P_2O_5	.023%	P.01%		.34 CaS
CaS	.340%	S.15%	Total slag	60.35
CO_2	39.63 %	Bases in excess 50.21 − 9.80		40.41
Total	100.003%	Slag from impurities 60.35 − 40.41 = 19.94		

Sulphur dissolving efficiency of the slag:
Slag required to keep 0.15% S in solution:

$$\frac{1.40y}{100} = 0.15$$

and $y = 10.714$ parts of slag per 100 parts of limestone.
Net slag available $60.35 - 10.714 = 49.636$
∴Sulphur dissolving efficiency $49.636 \times 100 \div 60.35 = 82.25$ %
Slag efficiency = Total slag (see above) 60.35 %
Fluxing efficiency = Bases in excess (see above) 40.41 %
Fuel required per 100 parts of limestone:

$19.94 \times 0.228 \div 0.7728 = 5.883$ coke

Sulphur in coke: $0.05883 \times 0.88 = 0.05177$
Sulphur in stone: 0.15 0.20177 S

Slag must be supplied for this sulphur.
See Coke and Limestone—Supplement—Cases II and III.

5.883 coke requires	$0.05883 \times 6.924 =$	0.407 base
and produces	$0.05883 \times 19.553 =$	1.150 slag
The 0.20177 sulphur requires	$0.20177 \times 24.16 =$	4.875 coke
The 0.20177 sulphur requires	$0.20177 \times 1.43 =$	0.289 base
The 0.20177 sulphur requires	$0.20177 \times 81.89 =$	16.523 slag
The 0.20177 sulphur produces	$0.20177 \times 86.61 =$	17.475 slag
Difference between slag produced and slag required		0.952 slag
Total coke required	$5.883 + 4.875 =$	10.758 coke
Total slag present	$19.94 + 1.15 + 0.952 =$	22.042 slag
Sulphur-free slag available	$22.042 - 16.523 =$	5.519 slag
Base available	$40.41 - (0.407 + 0.289) =$	39.714 slag
Sulphur in coke	$0.10758 \times 0.88 =$	0.09467
Sulphur in stone	0.15	0.24467 S

Sulphur in slag $24.467 \div 17.475 = 1.40\%$

One part of limestone:
requires 0.10758 parts of coke
furnishes 0.05519 parts of sulphur-free slag
furnishes 0.39714 parts of net available bases
furnishes 0.22042 parts of sulphur saturated slag

COST—SULPHUR INCLUDED:

Limestone costs	$1.10	×1.	÷0.39714 =	$2.7698
Coke costs	$2.20 \times 1.12 \times 0.10758$		÷0.39714 =	.6675
Slag costs	0.20	×0.22042	÷0.39714 =	.1110
			Total	$3.5483

Deduct for sulphur-free slag—See Coke and Limestone—Supplement, Case I.
$0.001 \times 2240 \times 0.05519 \div 0.39714 = $0.3113
Net cost per ton of 2240 pounds of net available base = 3.237
Net cost per ton of 2240 pounds of limestone,
$3.2193 \div (1 + 0.39714) = 1.279$

COST—SULPHUR NOT INCLUDED:

One part of limestone

requires	0.05883 parts of coke			
furnishes $0.4041 - 0.00407 = 0.40$	parts of net available base			
furnishes $0.1994 + 0.0115 = 0.2109$	parts of slag			
Limestone costs	$1.10	×1.	÷0.40 =	$2 750
Coke costs	$2.20 \times 1.12 \times 0.05883$		÷0.40 =	.362
Slag costs	0.20	×0.2109	÷0.40 =	.011

Total cost per ton of 2240 pounds of net available base $3.123
Total cost per ton of 2240 pounds of limestone $3.123 \div (1 + 0.40) = $1.249
Cost due to sulphur alone, per ton of 2240 pounds of limestone (no cost for reduction included) $1.279 - 1.249 = $0.030

COKE AND LIMESTONE—SUPPLEMENT

As sulphur plays such an important part in the blast furnace operations, where its presence in the slag must not exceed a certain limit, more or less dependent on local conditions, great care must, of course, be taken to produce sufficient quantities of the slag, in order to keep the sluphur on hand in a safe solution. While sulphur is transferred into the blast furnace through the medium of most anything that is charged into it, it is principally coke, however, that is the source of this element. If it were not for the coke, hardly any precautions would be needed, as the slag, that would have to be made anyway, usually is more than sufficient to take care of the smaller amount present in ore and flux. For calculating the relative cost of any kind of material entering the blast furnace it will therefore be convenient to have standard figures on hand relative to the amount of coke, flux, etc., necessary to put a unit of sulphur into the slag, thereby producing a standard sulphur solution. The sulphur in question will, of course, be the surplus amount left over after the slag on hand has been satisfied.

Calculations given below are examples and must be modified to suit local conditions. Results are, however, standards and should be made up once for all to be used during a period of say one year or during the time the standard analyses of coke and limestone are in force. A standard sulphur solution must also be adopted. There will now be five different cases to consider:

Case I. Limestone, sand, or its equivalence, and coke added.
II. Net base, sand or its equivalence, and coke added.
III. Net sulphur-free slag, net base for coke ash and coke added.
IV. Net sulphur-free slag, limestone for coke ash and coke added.
V. Limestone, sand or its equivalents and fixed carbon added.

In examples, given below, our standard analyses of coke and limestone (see under those items) have been utilized; also a sulphur solution of 1.40% S.

CASE I

LIMESTONE, SAND OR ITS EQUIVALENCE, AND COKE ADDED:

Sulphur in slag from limestone and sand or its equivalence ×%
Sulphur in slag from coke 3.943%
Sulphur in the final slag 1.40 %

Slag required to keep one part of sulphur in ×% solution $= \frac{100}{\times} = 81.433$

Slag shall have acids = bases.
Acids must be brought in from other sources than the limestone; this may be sand or its equivalence.
Slag from sand or its equivalence = y

Slag from limestone $= \frac{100}{\times} - y$

Slag from limestone is of 82.25% sulphur dissolving efficiency.

$\therefore$ Slag from limestone $= \left(\frac{100}{\times} - y\right) \div 0.8225$

Limestone is 60.35% slag efficient.

$\therefore$ Limestone $= \left(\frac{\frac{100}{\times} - y}{0.8225}\right) \div 0.6035$

$\text{Bases} = 0.4041\left(\frac{\frac{100}{\times} - y}{0.8225} \div 0.6035\right)$

But acids = bases.

$\therefore y = 0.4041\left(\frac{\frac{100}{\times} - y}{0.8225} \div 0.6035\right)$

and sand or bases $= y = \frac{40.41}{0.9x}$ — 36.545

Limestone required $= \left(\frac{40.41}{0.9x}\right) \div 0.4041 = \frac{100}{0.9x}$ — 99.433

Slag from limestone $= 0.6035\left(\frac{100}{0.9x}\right)$ — 54.576

Total slag $= \frac{40.41}{0.9x} + \frac{60.35}{0.9x} = \frac{100.76}{0.9x}$ — 91.121

Carbon to melt this slag $= 0.228\left(\frac{100.76}{0.9x}\right)$ — 20.776

Coke is 77.28% carbon efficient.

$\therefore$ Coke $= 0.228\left(\frac{100.76}{0.9x}\right) \div 0.7728$ — 26.882

Slag from coke $= 0.2297[0.228\left(\frac{100.76}{0.9x}\right) \div 0.7728]$ — 6.175

$\therefore \frac{100.76x}{100\,(0.9x)} + \frac{3.943}{100}\left\{0.2297[0.228\left(\frac{100.76}{0.9x}\right) \div 0.7728]\right\}$

$= \frac{1.40}{100}\left\{\frac{100.76}{0.9x} + 0.2297[0.228\left(\frac{100.76}{0.9x}\right) \div 0.7728]\right\}$

and $x = 1.228\%$

One part of sulphur requires therefore:

limestone to flux coke	$0.1713 \times 26.882 =$	4.605	
limestone for one part sulphur		= 90.433	95.038 stone
containing			38.400 base
sand or its equivalence			36.545 sand
coke			26.882 coke
slag produced: From sand or its equivalence		36.545	
From stone		54.576	
From coke		6.175	97.296 slag
Sulphur in stone	$95.038 \times 0.0015 =$	.14256	
Sulphur in coke	$26.882 \times 0.0088 =$	.23656	
Sulphur in base for these calculations		1.	1.37912 S
Sulphur in slag (per cent)	$137.912 \div 97.296$	= 1.417	%

The cost of slagging one pound of sulphur will be:

for coke	$\$2.20 \div 2000 \times 26.882 =$	$0.0295
for stone	$1.10 \div 2240 \times 95.038 =$	.0467
for sand or its equivalence	$1.10 \div 2240 \times 36.545 =$	.0108
for slag	$0.20 \div 2240 \times 97.296 =$	.0087 $0.0957

The value of one pound of sulphur-free slag will be: $0.0957 \div 97.296 = \$0.001$

CASE II

NET BASE, SAND OR ITS EQUIVALENCE AND COKE ADDED:

100 parts of coke require of net bases	9.63 − 2.706 =	6.924
100 parts of coke furnish of slag	12.629 + 6.924 =	19.553
Net bases added in per cent of total slag		35.41 %
Sulphur in slag	88 ÷ 19.553 =	4.50 %

Using these figures in formula of Case I we get:

$x = 1.2212\%S$

$\text{Slag} = \frac{100}{1.2212} =$ — 81.89

per one part of sulphur:

Coke	$0.228 \times 81.89 \div 0.7728 =$	24.16
Slag from coke plus bases added	$24.16 \times 0.19553 =$	4.72
Total slag	81.89 + 4.72 =	86.61
Bases in coke slag added	$4.72 \times 0.3541 =$	1.67

Added thus:

Coke		24.160
Base	(81.89 ÷ 2) + 1.67 =	42.615
Sand or its equivalence	81.89 ÷ 2 =	40.945
Slag produced		86.610

Sulphur in coke	$0.2416 \times 0.88 =$	0.2126
Sulphur in base for these calculations	1.	1.2126 S
Sulphur in slag (per cent)	$121.26 \div 86.61 =$	1.40%

CASE III

NET SULPHUR-FREE SLAG, NET BASE FOR COKE ASH AND COKE ADDED:

This is the same as Case II, with the following modifications added:

Coke	24.160
Base	1.697
Slag—half acids, half bases	81.810
Slag produced	85.600

CASE IV

NET SULPHUR-FREE SLAG, LIMESTONE FOR COKE ASH AND COKE ADDED:

In this case figures for coke as shown in Case I must be used

$\frac{x}{100} \cdot \frac{100}{x} + \frac{3.943}{100}\left\{0.2297[0.228\left(\frac{100}{x}\right) \div 0.7728]\right\} =$

$\frac{1.40}{100}\left\{\frac{100}{x} + 0.2297[0.228\left(\frac{100}{x}\right) \div 0.7728]\right\}$

and $x = 1.2277$

slag = 100 ÷ 1.2277 =		81.45
per one part of sulphur:		
Coke	$(0.228 \times 81.45) + 0.7728 =$	24.03
Slag from coke plus that from stone to flux ash	$24.03 \times 0.2297 =$	5.52
Total slag	81.45 + 5.52 =	86.97
Added thus:		
Coke		24.03
Stone for coke ash	$24.03 \times 0.1713 =$	4.12
Slag—half acids, half bases		81.45
Slag produced		86.97
Sulphur in coke	$0.2403 \times 0.88 =$	0.21146
Sulphur in stone	$0.0412 \times 0.15 =$	0.00618
Sulphur for base for these calculations	= 1.	1.2176 S
Sulphur in slag (per cent)	121.76 ÷ 86.97 =	1.40 %

CASE V

LIMESTONE SAND OR ITS EQUIVALENCE, AND FIXED CARBON ADDED

Use formula in Case I, eliminating coke and substituting 1.40% for x.

$\therefore$ Slag $100 \div 1.40 =$ 71.43

$y = 0.4041\left(\frac{71.43 - y}{0.8225} \div 0.6035\right)$

Sand or base = y =		32.07
Stone	32.07 ÷ 0.4041 =	79.36
Slag in stone	$79.36 \times 0.6035 =$	47.89
Total slag	32.07 + 47.89 =	79.96
Added thus per one part of sulphur:		
Fixed carbon	$79.96 \times 0.228 =$	18.23
Stone		79.36
Sand or its equivalence		32.07
Slag produced		79.96
Sulphur in stone	$0.7936 \times 0.15 =$ 0.119	
Sulphur in base for these calculations	1.	1.119 S
Sulphur in slag (per cent)	$111.90 \div 79.96 =$	1.40%

REPORT NO. ON LIMESTONE CONSUMED AT BLAST FURNACE NO.
During the week ending: Date: 19

Date	Limestone Consumed: Shipment No.	Limestone Consumed: Weight in Tons of 2240 Pounds	Analysis: SiO_2 %	Analysis: Al_2O_3 %	Analysis: Summated Acid %	Analysis: P %	Analysis: S %	Stone Efficiency: Daily: =100−[Col. 6+(1.79×Col. 6)] For Week End Average see Below %	Weight of Useful Stone Charged Into the Bl. Fce. =Col. 3 $\left(\frac{100-\text{col. 9}}{100}\right)$ Tons	Remarks
1	2	3	4	5	6	7	8	9	10	
Total and average										

*AVERAGE CONDITIONS FOR THE WEEK

Average analysis:		Going to the slag:	
SiO_2	5.80 %	5.80	
Al_2O_3	4.00 %	4.00	9.80 acids
CaO	46.54 %	46.54	
MgO	2.78 %	2.78	
FeO	0.89 %	0.89	50.21 bases
P_2O_5	0.023%P 0.01%		0.34 CaS
CaS	0.340%S 0.15%	Total slag 60.35	
CO_2	39.63%	Bases in excess 50.21 − 9.80 = 40.41	
Total			

Stone efficiency: 100 − [9.80 + (1.79 × 9.80) + 0.023 + 0.340] =	72.30 %
Flux efficiency = bases in excess =	40.41 %
Slag efficiency = total slag =	60.35 %
Sulphur dissolving efficiency (see calculations)	82.25 %
Cost per ton of 2240 pounds of net available base	$3.219
Cost per ton of 2240 pounds of limestone	1.279
Cost per ton of 2240 ounds pof limestone due to sulphur alone	0.030

*Figures inserted are for exhibition only.

Electrochemical War Supplies

A Report of the Papers Presented at the Meeting of the New York Section of the American Electrochemical Society on February 11

Such a varied and attractive program of papers on "electrochemical war supplies" had been arranged for the meeting of the New York Section of the American Electrochemical Society on February 11, 1916, that the attendance broke all records. Not even standing room was left, and for the first time in the history of the Chemists' Club it became necessary to close the outside doors in order to keep within the police regulations as to the capacity of the hall.

Dr. **Colin G. Fink**, chairman of the New York section of the American Electrochemical Society, in opening the meeting said that it had been arranged to bring before the public a few of the remarkable achievements of American electrochemistry. "Owing to the fact that the dyeing industry of this country was not comparable to that of Germany, the American chemist has been branded as incompetent. The people as a whole are sadly ignorant of the wonderful accomplishments of the American electrochemists; they do not know and have never realized that the electrochemical industry of the United States is the very foremost of the world. Furthermore, the electrochemist is a very important factor in national preparedness."

The Problem of Preparedness

Mr. **W. L. Saunders**, Chairman of the Board of the Ingersoll-Rand Co., President of the American Institute of Mining Engineers, and Vice Chairman of the Naval Consulting Board, was the first speaker. It is hardly necessary to say that he spoke very well. By some funny stories cleverly told—one of them how he once got a prize in chemical experimental work in his student days—he got his audience quickly into the best of humor and then launched into a discussion of preparedness.

The subject of preparedness is one in which I am very much interested. I cannot find myself getting into enthusiasm on the subject as to whether or not we should have an army of four hundred men or a million men; whether it should be a Continental Army or a State Militia, whether we should have instruction compulsory or instruction in the schools. I cannot get myself enthusiastic on the subject as to whether we shall have thirty-three dreadnaughts, forty-three or twenty-three, or whether we shall have a certain number of torpedo boats in proportion to a certain number of fast cruisers. All that, it seems to me, is a question of evolution. We are new in this question of preparedness. We are new as a war-like people. We do not know anything about it, and we had better reach a conclusion on the subject through deliberation and by a gradual process. But there is one thing that it seems to me that we do know—and if we do not we ought to know it—and there is one line of action in which we ought to begin at once, and that is, we should *begin at the bottom and prepare our industries.*

The first consideration is the industrial consideration of the country. Mines and mills and works and factories we have in large abundance. But they are all separated and disassociated, there is no relation between one and the other, there is no relation between any of the industries of the United States or the mines of the United States and the Government at Washington. You hear of a good many large concerns making large amounts of ammunition and making a good deal of money out of it. It is a new business, and it is attractive to them financially, but they know nothing about the relation of the United States to ammunition. They know nothing about what kind of shrapnel or shells the United States would require in case we were in trouble. In other words, the first question and the most important consideration in talking about preparedness against attack, is to have the industries of this country not only acquainted with each other and co-related, but in touch with the Government of the United States, so that the Government of the United States might tell them exactly what might be expected of them in case we ever get in trouble. No such thing has ever been done in this country. We know nothing about it, yet what little experience some of us have had on the Naval Consulting Board, we are inclined to believe that when the inventory is taken of the condition of the United States, the strength of the United States for peace or war will be found to be absolutely amazing. We do not know what we have got here in this country.

The Steel Corporation directors and officers know what they have got in the shops of the Corporation. and other concerns may be well acquainted with what the conditions are of their work, but we do not know the enormous volume and strength of the industries of the United States which might, if co-related and mobilized, put this country into an impregnable position against attack.

It seems to me, ladies and gentlemen, that it is far more important in the interests of peace and safety, for the United States to train its men in the works and have them organized so that they know what to do and do it efficiently, than it is to get them out in the trenches, or over at Plattsburgh, or out on the seas, getting trained to shoot guns, because if we got the organization in the works, and if we got the maximum resources in this country in iron and steel and coal and copper, we can get the men and we can train the men in a very short time to know how to handle those munitions and to oppose the strongest foe that the world can bring against us.

Mr. Saunders pointed out that the yearly coal consumption per capita indicates the industrial prosperity of a nation. This is five tons for the United States, four tons for Germany, four tons for England, 1.6 tons for France, 0.25 tons for Russia.[1]

Anybody who has been in Russia as I have travelled over it several times, can see that the people of Russia, while they are intelligent, good people, yet they are not industrially prosperous. In other words, the individual in Russia can only produce what he can do with his hands. He will go out into the field and hoe and raise potatoes and cabbage. If he is working in the shops, he is working in some small establishment where his productivity is very limited. The same individual in the United States may produce ten to twenty times as much, because his work is done in factories on a large scale, where the productivity of the individual is multiplied five, ten and twenty times.

I have gone rather at length into this subject only to make plain the first point that is in my mind, and that is that industrially in times of peace, we are the strongest nation in the world. The three foremost industrial nations that I spoke of, the United States, Germany and England, produce and consume ninety per cent of the iron ore in the world. That is another indication of industrial prosperity.

Now, what is the difference between the United States and Germany, for instance? We have our industrial prosperity almost perfected on lines of peace. I venture to say that if the United States Steel Corporation or the Harvester Corporation or the Standard Oil Company, or any other of these large concerns which are run so well, so economically and so efficiently, were lifted bodily from this country and planted in either England or Germany, they would not be run any better. If they were lifted bodily and planted in Russia, they would fail, they would not be a success. I do not believe France could run them. Certainly Spain could not, nor Italy, and to take an exaggerated illustration, suppose they were lifted into China, can you imagine a great industry like the Steel Corporation run efficiently and profitably in China? No, it is impossible. In Japan they could not be run profitably. I have been in Japan and I have watched and studied the Imperial Steel Works with the

[1] Compare the paper by J. R. Finlay, this journal, Sept. 1, 1915, vol. XIII, p. 547.

Government's money behind it, and yet they do not know how to produce steel rails as cheap as we do in the United States. They have not yet the efficient step that we have got in this country. Now Germany has got it, and Germany has got it not only for peace, but she has got it for war. But we have not got it for war, and it will take a long period of years to get it for war. I doubt whether our industries can be efficiently organized on a war basis in a period of even ten years, but we had better begin now. We do not control the world, we are only a small part of it, and a large part of it is in a conflagration at the present time. We had better prepare and protect ourselves and see that our house is in order, and we ought to begin at the bottom, and the bottom is in the industries of the United States.

And as a foundation we have the chemical industries of the United States, because chemistry is at the bottom of all our industry. We discover through chemistry. Chemistry is the basis of all our industrial prosperity, not only in mining and metallurgy, but in the arts in general. My whole experience in life has been a part of chemistry. I have been in business as an engineer, and week after week, in general work that I have done in connection with large corporations and in the management of work, have I found chemistry of advantage. Always questions come up wherein chemistry cuts an important figure—even in the question of drill steel, and why drill steel breaks under the hammer, and so, ladies and gentlemen, in conclusion I want to tell you that in industrial life, in both peace and war, the chemist is of the greatest importance.

Mr. **Lawrence Addicks**, president of the American Electrochemical Society, was unable to be present on account of illness, but had sent a letter in which he called attention to the fact that the war in Europe has accomplished two very important steps toward the military preparedness of this country. It has given a great many manufacturing concerns experience in adopting ordinary machinery to the special uses of turning out arms and ammunition, and it has sufficiently disturbed our imports to emphasize what would be our weak spots in self support in time of isolation. Aside from the broader view that nearly all production or manufacture contributes to war supplies, electrochemistry plays an important part in the production of some indispensable items—copper, aluminium, electrolytic zinc, various gases such as hydrogen, oxygen, chlorine, and acetylene, and finally the fixation of atmospheric nitrogen. Submarines could not be operated without the storage batteries and we must include wireless telephony. It may be included if the chemist and the electrical engineer put their heads together and do a little team work.

Fixation of Atmospheric Nitrogen

Mr. **W. S. Landis**, chief technologist of the American Cyanamid Company, said there was a widespread idea that Germany had been well prepared for the present war, as it had had large plants for atmospheric nitrogen fixation which could be diverted from fertilizer manufacture to munition manufacture, and that the development of an atmospheric nitrogen fixation industry requires years of work.

As a matter of record Germany at the outbreak of the European war possessed three cyanamid factories with a combined capacity of but little over 50,000 tons of cyanamid per year. There were then no arc processes at work in the country, and the Haber process was producing a comparatively small quantity of sulphate of ammonia.

In contrast with this Germany has to-day a production on an annual basis of almost 500,000 tons of cyanamid, and nearly 10,000 tons of arc-process nitric acid, all of which has been built and set into operation within eighteen months. Even the Haber process has been considerably increased in capacity, though the plant at Opau suffered greatly, though indirectly, from an aeroplane visit. The present German investment in these atmospheric fixation processes is now over $100,000,000, and Germany is enabled to meet not only its agricultural requirements for nitrogen, but its munition demands as well. In other words, Germany is now fixing atmospheric nitrogen in quantity such as to replace the entire importation of nitrogenous materials amounting annually to approximately 850,000 tons of nitrate of soda and 40,000 tons of nitrate of lime, plus an indefinite amount of Norwegian cyanamid amounting probably to 20,000 tons annually. The munition plants are consuming nitric acid at a rate of 250,000 to 300,000 tons per year in addition to the above agricultural and manufacturing requirements.

Germany at the outbreak of the European war had no commercial plants oxidizing ammonia, though the processes now in use were then fairly well developed. It was not until after the beginning of the war that these processes were put to work on a large scale, and the tremendous amount of nitric acid required to maintain her powder supply is now almost exclusively obtained from these oxidation processes.

These figures are certainly impressive, illustrating what eighteen months can do toward meeting an emergency if the necessary funds are forthcoming and an intelligent organization directs their expenditure. We can well appreciate that this great feat was accomplished only by terrific strain upon the technical staff which had charge of the work, and undoubtedly at an extravagant cost.

The manufacture of cyanamid on this side of the Atlantic is conducted in Canada under American direction. It is carried on at a higher efficiency than in the German plants and a higher-grade product is made. Our transformation into ammonia is at an equal efficiency to theirs, and the operation is conducted with less men and with a simpler form of apparatus.

We further have in this country intimate knowledge of the design and experience in the operation of the successful ammonia oxidation process, and it will only be a matter of a short time now when a fair-sized plant will be producing nitric acid from cyanamid by this process in the United States. There are no problems concerned therewith, the solution of which is not now resident in the United States, and, therefore, we feel that this country is to-day in as good, if not in a better position to supply its own nitric acid for munition purposes than Germany was at the beginning of the war in July, 1914.

Hydrogen for Military Purposes

Capt. **E. D. Ardery** of the United States Army was the next speaker. He gave an outline of the various properties and general uses of hydrogen gas and then took up its applications for military purposes where it is used mostly for inflating balloons and also (in combination with oxygen gas) for welding and cutting. The lifting capacity of hydrogen gas is different, depending on the process of manufacture used; it usually ranges between 1.175 and 1.195 kg. per cubic meter.

Captain Ardery outlined the various methods for making hydrogen, of which there are many. The old method using iron filings or zinc with dilute sulphuric acid, the aluminium and caustic soda process used in the Russo-Japanese war, the silicon or ferrosilicon and caustic soda process and the method using a powdered mixture of ferrosilicon and sodium calcium oxide used by the French were mentioned. The calcium hydride or hydrolytic process, utilizing the reaction between calcium hydride and water, has also found some use abroad, the chief objection to it being its high cost. Hydrone is a substance made in this country, which in contact with water generates hydrogen. The process of passing steam over red hot iron has also found application as has the coke and oil process. (For further information on these processes see this journal, Vol. IX, page 157, and Vol. XIII, page 567.)

The United States Signal Corps has made experiments on the refrigeration of illuminating gas for producing hydrogen and at Port Omaha, Neb., the army installed a plant for the generation of hydrogen by the electrolysis of water.

The chief objection in military work to utilizing the hydrogen set free from the electrolysis of water or salt solutions is the problem of compressing and transporting this gas. Portable plants are necessary to follow the army. Various portable plants are in use of various sizes. Hydrolith or calcium hydride and hydrone are portable, as are also the installations

of several of the other processes. The Germans have achieved much success in transporting hydrogen gas in cylinders under pressure and also in pipe lines. It is claimed that in Germany large balloons are filled in 20 min. from hydrogen compressed in cylinders.

Niagara the Commercial Research Laboratory of the Nation

Mr. **Albert H. Hooker,** works manager of the Hooker Electrochemical Co., of Niagara Falls, N. Y., was the next speaker. He said that while the title, "New War Products," had been assigned to him for his paper, it hardly fitted the topic he had in mind. "However, it will do as well as any other to wander from."

One evening at Niagara Falls it was my fortune to sit next to an attorney (Mr. Scovele), who told me that some years ago he had been commissioned to visit London and place with a group of financiers an early issue of bonds of the Ontario Power Company. He was asked by these financiers what use his principals proposed to make of this development of about one hundred thousand horsepower. His reply to their question impressed me, for he stated that "when the Niagara Falls Power Company started their tunnel (about 1891), not one of the companies now using that power was in existence, and not only that but not one of the products now made by those companies, through the use of that power, was then known to commerce."

This statement, sweeping as it sounds, is nearly true, for aluminium, carborundum, alundum, silicon, artificial graphite, calcium carbide, cyanamide, ferrosilicon, ferrochromium, ferromanganese, along with electrolytically produced caustic soda, sodium, chlorine, chlorates, chloroform, carbon tetrachloride, etc., are all commercial products of the last twenty-five years, most of them having been developed through the impetus given by this Niagara Falls power development. The few that were made earlier were little more than chemical curiosities.

Cannot these be rightly spoken of as "new war products"? Certainly they played no part in the munitions, armament and equipment of our Civil War nor the War of 1870. But in what a sorry plight would any manufacturing country be to-day, and particularly either side of the present warring nations, without these materials!

Carborundum, alundum, aloxite, crystolon are all artificial abrasives used in modern grinding machinery for the manufacture of automobiles, guns, shells, shoes, armor plate and for the grinding of tools. There is hardly an industry where the tremendous decrease in production and increase in cost would not be felt were we without these artificial abrasives produced by the electric furnace at Niagara. Ferrosilicon, ferromanganese, ferrochromium, ferrotitanium, ferrotungsten and ferromolybdenum are all products which have become necessities in the steel furnaces of to-day, to the point where possibly 75 per cent of the steel production of the United States is dependent upon the products from the electric furnaces of Niagara Falls. What would we do in the way of modern open-hearth steel without ferrosilicon, or armor plate without ferrochromium, to say nothing of high-speed tool steels and all they mean for modern machinery manufacture, whether these machines are sewing machines, automobiles, agricultural machinery, steam engines, pumps, cannon or shells? England's embargo on ferroalloys would have crippled the industries of this country in a far more serious manner than the loss of all the German dyes, had not one of the companies at Niagara been able to divert a large block of power from the production of calcium carbide to the production of ferrochromium, ferrosilicon, etc. And still this would not have been possible were not the electrochemists, engineers and operatives already at hand and skilled in the art; and further this might not have been possible without additional power development had we needed at the same time, as Germany does to-day, every last ounce of carbide for the fixation of nitrogen.

Caustic soda is all important in the manufacture of soap, for the refining of oils, the mercerizing of cotton to produce artificial silk, and a hundred familiar uses, yet it takes on additional importance to-day when we think of caustic melts in the production of dyes, the manufacture of picric acid and other nitro explosives. Sodium we seldom see, and are likely to connect this substance with a few lecture experiments, yet metallic sodium made at Niagara Falls forms the basis for all of the cyanide in which so many of our mines depend for the recovery of the precious metals. When the German supply of cyanide was cut off, it looked for a time as if many mines would have to close. Here again an increase in production made possible a restored balance, and fortunately a little power was available for the purpose.

Upon bleaching powder, liquid chlorine and hydrochlorites we depend for the bleaching of our cotton cloth, the bleaching of wood fiber for the production of book paper, the sterilization of water supplies of many of our cities thus preventing typhoid fever, dysentery and other diseases. The electrolytic plants at Niagara Falls form the center of this important industry. They, as well as all other electrolytic plants in the country, are dependent upon Acheson graphite made at Niagara Falls for their graphite electrodes. These chlorine products have all taken on a new interest, liquid chlorine as a means of offense and defense, chlorinated benzol, etc., as necessary intermediates for the production of dyes and explosives. Are these new plants and the knowledge and skill required to operate them—experience obtained at tremendous cost—to be scrapped and lost after the present crisis is over? Or, are we to continue the operation along the line of peaceful, constructive manufacturing, increasing our skill and knowledge and retaining a skilled force of workers, chemists, engineers and operatives? Much will depend on the policy of our Government.

Is not Germany, with her supply of Chilian saltpeter, cut off, absolutely dependent upon the fixation of nitrogen by the electric furnace, the electric arc or the use of electrolytic hydrogen for all of her nitro explosives? Were it not for her foresight in considering this eventuality and subsidizing the development of the nitrate industry in Norway with its cheap water power, and then carrying the development work to a point where in an emergency like the present even power produced from coal could for the time supply her needs for nitric acid from internal sources, how otherwise could she stand to-day with England's fleet in command of the means of communication with the Chilian saltpeter deposits?

A NEW PROPOSAL OF NIAGARA FALLS POWER DEVELOPMENT

What are we doing to-day to supply our needs in a like emergency? I have a remedy to propose, and one which I feel it a duty to urge, for your earnest consideration.

As this was written, I saw from my window the waters of the Niagara River flowing by with a capability of being developed into perhaps five million horsepower—the most uniform and constant water power in the world. I am very fond of the impressive beauty of its mighty falls and the wonderful gorge and rapids below, and only as a last resort in the event of a *national defense necessity* would I do anything to injure that landscape. Such injury, however, is not necessary. As I study the daily moods of the falls, I see the ebb and flow of water due to the direction and velocity of the wind on Lake Erie, making far greater difference in the volume of water passing over the brink of the Falls than is caused by the present diversion of water producing some five hundred thousand horsepower. I also see that the beauty of the falls is not at its best when the largest volume of water is passing over its brink. From careful study I am satisfied that well over one million horsepower more could be diverted, and not an iota of injury would be done to the scenic grandeur of the cataract if a little engineering skill were used in placing the proper brakes and deflectors. If this is true, think of the tremendous increase in national efficiency and preparedness this development would mean. Arrange now with Canada for a development of water power at Niagara three times as great as at present—the time is ripe.

For every one hundred thousand horsepower diverted, provide that say ten thousand horsepower shall be devoted to the fixation of atmospheric nitrogen. The more varied the methods used the better. Make Niagara the commercial research laboratory of the nation in this field by supplying private enterprise with power at nominal cost for this purpose. Under these conditions, power, even if developed by private enterprise in large amounts, could in the above percentage be supplied as cheaply if need be as Norwegian power, and would be infinitely better adapted and centralized for the purpose. Such power would be within a night's ride of Washington, New York or Chicago. Already located at Niagara is the largest group of electrochemical workers in the world. Such a development would double their number. Is it through lack of foresight or " a dog in the manger policy" that some of our largest and most important electrochemical industries are even now compelled through lack of cheap power to go to Norway and other fields, there to start the training of a foreign army of electrochemical workers upon foreign soil, while unused water which could be utilized without injury goes to waste?

I have been told that the Niagara River is a border stream; that plants situated near that border would be particularly open to foreign attack. Conceding only that Eng-

land be our enemy, this is true. But did Germany give heed to an even stronger reason against making her experimental and peaceful development in Norway, where as at Niagara the economic conditions were right?

Not in a day, a month, nor a year can these problems, alike of peace and war, be worked out, the equipment developed and installed, and above all, the workers trained. The goal is an ever-increasing internal independence both as regards food and chemicals. For an increasing population this may well mean the regeneration of a worn-out soil, the refertilization of our farm lands from New England to the West with ammonia and nitrates from the air. Every farmer, every bread eater is interested in the result. Let me in this connection read two extracts which I recently clipped from the daily press:

"London, Jan. 21.—The urgent necessity of speeding up the supply of munitions has determined the Government to put into force immediately plans for the dilution of skilled labor with semi-skilled, unskilled and female workers in all controlled establishments. In a statement on the subject in the House of Commons to-day Premier Asquith announced that the Government was convinced that this plan offered the only prospect of securing a sufficient supply of munitions to enable the war to be brought to a speedy and successful conclusion. 'Any lack of munitions,' continued the premier, 'would exact a heavy toll in lives of soldiers. It is quite impossible that foreign supplies can take the place of the home production of munitions, but even if those sources of supply were indefinitely extended, the immense demand thereby caused upon our financial resources and our shipping would present insuperable difficulties.' Premier Asquith stated that both the owners of the controlled establishments and the representatives of the trade unions had loyally pledged themselves to support the Government in the scheme of labor dilution. Considerable progress had already been made in certain districts, but he regretted that what had been accomplished fell lamentably short of the national requirements in the present emergency.

"Brigadier General Crozier has given some figures to the Senate Committee on Military Affairs which should put an end to the movement to have the Government build its own munitions plants. He estimates that the cost would be about $400,000,000, and that 750,000 workmen would have to be employed. This would supply 1,000,000 men in the field and a reserve of 1,000,000 men with guns and ammunition. General Crozier believes that the Government could do better with private manufacturers, whom he would have the Government encourage. As has been proposed, the Government could supervise the manufacture of arms and ammunition and in a considerable degree regulate prices."

The provision of electrochemists, mechanical engineers and operators in these specialized industries in times of peace as an emergency precaution is fully as important as compulsory military service and should be considered as an element of the same broad plan. My wife says she objects to raising her boy to be a soldier, and yet would be the first to tell him to go to the front if his country needed him. Instead, however, I am training him to be a chemical engineer, where I feel that in times of peace and without economic loss he will be in constant training to serve his country's needs to the highest degree should war arise.

Think you that Germany and Switzerland are only interested in the electrochemical and synthetic dye industries because of their economic value in time of peace? They are of tenfold greater value as measures of preparedness. The same benzol, toluol, caustic soda, nitric acid, chlorine and sulphuric acid used in times of peace for the manufacture of dyes are used in times of war for the various nitro explosives; the same equipment is used and the same army of skilled chemists and workers familiar with the latest details of nitration process are in constant training.

Should we not consider the training of this industrial army, the preservation of our growing dye industry, the development of our water power and electrochemical industries as a matter of particular urgency now as a measure of preparedness for national defense?

Metallic Magnesium

Dr. **William M. Grosvenor,** consulting chemical engineer, New York City, then presented a paper on metallic magnesium (one of the promising baby electrochemical industries of this country, as the chairman remarked). In the introduction he cleverly offered his "qualifications (or apologies)" for speaking on the subject. "There are but two: The first is what I do not know about it. The second what I suspect but am not at liberty to tell."

THE ELEMENT

You all know the chemical position and character of magnesium, leading member of the alkali earth division of the second group, atomic weight 24, closely related in its properties on the left with Na 23, on the right with Al 28, with Be 9 above it and Ca 40 below. Note the comparative lightness: Sp.G. Mg. = 1.75, Na = 0.98, Al = 2.6, Be = 1.64, Ca = 1.6. Also the melting points: Mg. = 750 deg., Na = 96 deg., Al = 660 deg., Be = about 900 deg., Ca. = about 760 deg. All are more or less soft white metals, all show great avidity for oxygen, decomposing water more or less readily. None except aluminium has found large commercial use, but of the others magnesium leads the list by a long distance.

USES

Its chief uses are:

Scavenging alloys, *i.e.* clearing up oxides of other metals and making far denser, cleaner, stronger and more homogeneous alloys. Valuable in aluminium nickel, copper, brass, bronze, etc., and special steels, because of its intense avidity for both oxygen and nitrogen.

Alloying itself, with aluminium or aluminium containing traces of one or more of the other metals, Cu, Ni, Zn, Pb, Bi, Sb, Fe, etc. It greatly modifies crystallography and physical properties, alloys readily with most metals, and melts at a convenient heat.

Illumination, as in military uses for shrapnel trailers, star bombs, flare lights, etc., and in photography for flashlights. Its easy inflammability (about 800 deg. C.), the high heat of combustion (134,000 cal.), the relatively low heat of vaporization (1100 deg. C.), the intensely white oxide produced and the high temperature of volatilization of this oxide are the essential factors.

MAGNITUDE AND PRICES

How much is used? A far more agitating question than how old is Anne. Records of imports for the year prior to the war indicated 38,000 lb. About 100 lb. a day, therefore, seemed to be a safe production to undertake. Prices before the war had been very steady around $1.45 per pound, but it seemed reasonably certain that the cost need not exceed $1 per pound. After the war began the prices being paid for remnants of imported lots quickly rose to $2.50.

Some of the first demands here were from wholly unexpected quarters, in surprising amounts and at amazing prices. The most urgent, almost pitiful demands, came from quarters that were not even suspected to be interested in the least. One consumer has contracted for 24,000 lb., another for 15,000 lb., these two alone taking for strictly domestic use more than was supposed to be the total importation. There are at least three other buyers of similar quantities, but exact amounts are not yet established by yearly contract, and even at present prices the consumption for strictly domestic use is about 50 tons.

We found that a great deal of the material was being imported under other names and most carefully disguised—secrecy being preferred to economy. Prices as high as $10 per pound were gladly paid at first for domestic product. For some months then the prices jumped around from $5 to $7.50, but every effort was made to reduce conditions to some sort of order by dealing direct with the consumer. This was partly the result of a deliberate policy for better and more intelligent service of the consumer's precise demands as to quality and delivery, but partly also the result of meeting quite unexpectedly the competition of our own product at prices from 25 per cent below to 50 per cent above the prices we had made. Some of New York's clever war brokers added 10 per cent each through a chain of four or five middlemen. Others assumed direct quotations to have already been through this process and knocked off 20 per cent, trusting that "real cash business" would squeeze down the middlemen they supposed to exist and still leave 5 per cent for the real seller. Now, however, for a number of months the price has been practically fixed at $5.50 per pound of "guaranteed 99 per cent," actually about 99.5 per cent. Occasionally a lot that has been picked up in the antebellum market for speculation is let go at lower figures or a lot of lower-grade material comes on the market from abroad, but there is practically no volume of these sales.

In spite of the beautiful appearance of the German bars they rarely exceeded 98 per cent and often fell as low as 96 per cent. The process of extrusion concealed impurities by drawing them out into minute threads. It is safe to say that the regular commercial grade of metal made here now is superior to anything ever imported.

REASONS FOR THESE PRICES

It may seem ridiculous to ask or pay such prices. Let us consider. The alloy market constitutes the bulk of the

business, and governs prices. In aluminium castings, for instance, about less than 2 per cent of magnesium cleans up the aluminium and leaves ¾ to 1½ per cent in the casting, about doubling its tensile strength, and quadrupling its resistance to shock or jar. It reduces the cost of machining more than 50 per cent, halving the number of resets on the cutting tool, giving clean cut machine surfaces, and permitting a polish to be secured with the last cut instead of a separate operation. With care, 1½ per cent of magnesium at $5.50 per pound is all that is needed, *i.e.* 8¼c. per pound of casting actually required to do the same work. The increase in strength means, in some cases, a reduction in weight of casting of 50 per cent. The reduction in casting weight is generally not less than 25 per cent. The weight of a pure aluminium casting may therefore be reduced if this 1½ per cent of magnesium is used by from 25 to 50 per cent. This is a great saving even at normal prices of aluminium since it amounts to about one-fourth of 20c., or 5c. With aluminium at 60c. it amounts to 15c. worth of aluminium saved for a stronger and more stable mechanical result. The saving in machine work alone when the casting is to require much machine work more than pays for the use of magnesium. So much for the consumer or user.

Now the manufacturer of magnesium has certain considerations (of necessity rather than mere excuse) for the high prices. Cost of production abroad prior to the war approximated $1 per pound. Sales in England were about $1.30 and here about $1.45 per pound. At that time $MgCl_2 6H_2O$ was selling for about $18 per ton. Present prices here are now about $60, nearly four times normal. Other chemicals used in the manufacture have increased to ten times their normal price.

One other factor, *i.e.* insurance, must be considered in two forms. First, the insurance against cut prices and dumping that may come immediately upon the close of the war, making the plant and market-development work absolutely worthless. Second, the insurance against partisan interference. As a matter of fact, in the case of two plants not a pound of material from either of which has gone for foreign military purposes so far as we know, there have been repeated efforts at molestation and some serious interruptions. Finally, there is the general consideration of relative price advance as compared with other materials: H_2SO_4, $12 to $60, or five times; nitric, 4c. to 12c., or three times; NaOH, 1½ to 5½, nearly four times; Na_2CO_3, 1 to 4, and numerous other commodities not directly affected by inability to import.

In considering prices it is well to mention separately export prices. Before the war nearly all the magnesium for England, as well as the United States and France, came from Germany. Since the war both France and England are producing in considerable quantities of excellent purity. This fact and the failure abroad to realize the strenuous conditions here, account for the unwillingness of buyers abroad to pay more than $3.50 for powdered metal (all the above named prices were ingot or bar).

PRESENT PRODUCTION

At present there is being produced here at two points about all the present alloy market will absorb, and an increase of plant is being made of about 25 per cent the present capacity. One other producer makes only about his own requirements. Two others are soliciting business, but have failed to fill orders—in one case the order is now over a year old and still stands unfilled. All told, we believe the present production is at the rate of something over a million dollars a year, and will be slightly in excess of the present domestic needs.

POSSIBILITIES

The use of the metal for scavenging purposes depends on price of metal compared with price of material to be scavenged. For use with copper, brass, bronze, etc., the magnesium can be used at far higher prices than for steel. But the big consumption of the material can only come when it directly replaces aluminium as the predominant metal in the alloy, and arrives at a correspondingly low price. It makes beautiful castings, machines easily and well, is about a third lighter than aluminium, and can be made about two to four times as strong. The coefficient of expansion reported is practically the same as aluminium. When properly pure (over 99.5 per cent), it is apparently quite as resistant to corrosion as aluminium, equal if not superior in electrical conductivity (about half that of copper), and superior in heat conductivity to aluminium (also about half that of copper).

PROCESSES

1. Reduction of fused $MgCl_2$ with Na.
2. Electrolysis of the fused double chloride, usually $MgCl_2KCl_2$.
3. Reduction with carbon. (Patented.)
4. Electrolysis of dissolved MgO. (Applied for.)
5. Reduction of fused $MgCl_2$ with Al. (Applied for.)
6. Reduction of oxide or carbonate to slag-forming residues. (Applied for.)

And some others.

The first process involves the production of metallic sodium, and we have been using the Castner process for this purpose to satisfy ourselves just what the sodium would cost and what the possibilities in this direction were. Existing conditions, the demand for sodium and sodium peroxide, forbid its consideration wth a minimum of about 2 lb. of Na consumed for every pound of magnesium produced and the necessity of producing dehydrated fused $MgCl_2$ to start with.

The second process has been perfected and is very largely used abroad. We have commercially used and studied the process here and, with the cheapest water power and chloride, prices under normal conditions by this process must rule above $1.

The third process, reduction with carbon, is absolutely fascinating in its possibilities. The product is a black or gray powder. Believing such a product would be valuable, the manufacture was carried out on a scale of about 25 lb. per hour. As the difficulty of selling the product became apparent, much time and effort were devoted to attempts to recover the metal in fairly pure form. Owing to serious objection both on the side of cost and regularity of product this process was superseded.

The other processes will be discussed on some other occasion when the engineering problems they involve are believed to be finally solved in the best way and the patent office has finished considering them. The chemical side of each has been thoroughly worked out, however, so that some conclusions may be drawn from the large laboratory or small commercial operations. These may be of considerable interest.

At least one of the processes appears to be adapted to produce directly metal averaging 99.6 per cent purity in tons per day instead of pounds. Laboratory tests give a raw material cost of 4c. per pound of magnesium, and indicate a fuel cost which approaches 3c. as a theoretical limit, though the practical figure will probably be several times as high. The final selection of various possible engineering means and methods remains to be worked out, but it scarcely seems possible that either labor or repairs should exceed 2c. per pound. Thus if commercial yields maintain the experimental level and three times the theoretical power is commercially required, we have prospects of a net factory operation cost (without interest, amortisation, insurance, patent, administration or selling) of 17c. per pound. If only 75 per cent yield is obtained this net factory cost would be about 22c., or a total cost with all overhead expenses of 35c. and a selling price of 40c. to 50c., according to tonnage.

It may be asked with perfect propriety: "Why talk about it now? Some fool will certainly want you to make a contract with him at lower prices, possibly at 50c. He will not realize that it is only the present price of $5.50 that justifies or even makes possible the thousand and ten-thousand dollar experiments that have been tried and must be tried again and perhaps again during the next three to five years before the tide turns. You will be pestered for years with this 17c. talk." We have carefully considered this probability. The men who are doing this work do not cultivate talkativeness as a preference. Just at this time, however, certain considerations of public welfare should take precedence of preference. National self preservation demands the subordination of personal interest. If we expect representatives at Washington to jettison the pork barrel, the army post, the high-tide navy yard, and political trading generally, and give us a fighting chance for our lives in the scrap that is certainly coming, we must set the example of considering national interest first. If we are to have the army and navy preparedness for which we have already wasted more money than Germany has paid for her wonderfully efficient fighting machine, if we are to have any preparedness instead of repairs or regrets, we must co-operate with all we have in service, information and suggestion.

Therefore, at the risk of criticism and possible financial sacrifice, it seems to be a duty at this time to point out what may possibly be expected of magnesium. Few realize the extent to which it is valuable in military work. One of the great foreign explosive experts stated that he would be glad to pay $1.50 per pound for 500 tons. A single contract for shrapnel being executed in this country would require about fifty tons. The illuminating bombs to make daylight over the enemies' works and trenches consume large quantities. The trailer attached to shells serves at night to show the effectiveness of the fire. For all these purposes mag-

nesium produces a result that cannot be approached by antimony or aluminium. Consider what it means to aeroplane, dirigible and motor construction, to high-speed engines of every type, to reduce weight one-third and double strength. A material that has a density of 1.75 and may be hot rolled to 35,000 lb. per square inch or cold rolled very much higher.

Although five or six men are being kept practically all their time on the development of these possibilities, the broad, quick development is a task for the energy of hundreds. Feeling the responsibility which knowledge of the possibility entails it became the duty of those in charge of this work to let others know and be active in their side of preparation, to apply the material.

Liquid Chlorine and Electric Steel

Dr. **G. Ornstein,** chemical engineer of the Electro Bleaching Gas Company, then read a paper, illustrated by lantern slides, on liquid chlorine. This paper was published in full on page 215 of our issue of Feb. 15.

Dr. **George W. Sargent,** vice-president of the Crucible Steel Company of America, spoke briefly and, in view of the late hour, promised to present his paper on electric steel at a future meeting of the society.

Electrolytic Zinc

The last paper on the program was by Mr. **W. R. Ingalls,** editor of *Engineering and Mining Journal,* on electrolytic zinc. In the absence of the author it was read in abstract by Dr. J. W. Richards.

Without any doubt, the most important thing in the metallurgy of zinc in 1915 was the inauguration of electrolytic zinc production direct from ore on a large experimental, even a commercial, scale at several places, the most important of these being at Anaconda, Mont., where the production of electrolytic spelter at the rate of about five tons per day was begun. The results are considered so favorable that the Anaconda company has commenced the erection at Great Falls, Mont., of a plant capable of producing 35,000 tons of electrolytic spelter per annum. With regard to the nature of the Anaconda process, Mr. Laist, who is responsible for it, has written me as follows:

I can hardly claim that we have accomplished anything especially new in this line, except in so far as we have done on a somewhat larger scale what had often been done before by others in the laboratory in a smaller way. Briefly, the process consists of concentrating the zinc ore, preferably by flotation, so as to make a concentrate with as little insoluble matter as possible and as rich in zinc as the nature of the ore allows. This concentrate is roasted in two of the furnaces of our copper-leaching plant, so as to produce a calcine containing from 2 to 3 per cent sulphur, most of which is present as sulphate sulphur. The temperature is not allowed to exceed 1350 deg. Fahr., under which conditions the formation of zinc ferrite is not pronounced.

The calcine, after cooling, is treated with a solution containing sulphuric acid, which dissolves the zinc and a little of the iron. A small amount of manganese dioxide is added for the purpose of oxidizing the iron, which is then precipitated by means of a small amount of powdered limestone. Any arsenic or antimony is carried down by the precipitated ferric hydroxide. The resulting solution contains nothing but zinc, cadmium and copper, and is separated from the residue by filtration. The residue contains the lead, silver and gold and part of the copper originally present. The solution is treated with metallic zinc to precipitate the copper and cadmium, and is then pumped through a clarifying filter-press into a storage tank, from which it goes to the electrolytic cells. The cell room contains forty-two tanks, which are in no way different from those commonly used for copper refining. Here the zinc is deposited on aluminium plates.

The solution from the cells contains sulphuric acid and is used for leaching a fresh charge. The zinc deposits on the aluminium plates are stripped off every 48 hr. and sent to the melting furnace. At the present time we are making about five tons of zinc per day of a high degree of purity.

I will add to this that the leaching is performed in Pachuca tanks, the lixiviant being spent electrolyte plus the quantity of fresh acid required. The anodes of the electrolytic cells are of pure lead. The solution is electrolyzed at a current density of 20 to 30 amp. per square foot of cathode surface, the general practice being about 23 amp. The voltage drop per cell varies from 3.8 volts at the head cell of the series (21 cells in cascade series) to 3.4 volts in the tail cell. Current efficiency is from 93 to 94 per cent.

Apart from the Anaconda work, the most ambitious plans carried on in 1915 were those of the Consolidated Mining and Smelting Co. of Canada, which continued the experimental work begun several years ago. In the last official report of this company it is stated that spelter of good grade has been produced at the rate of 1000 lb. per day from ore from the Sullivan mine, and that the results were sufficiently promising to warrant the building of a plant capable of producing 25 to 35 tons of spelter daily. Construction of this plant is well advanced, and it is expected to be in operation early in 1916.

Electrolytic zinc was also produced in 1915 on an experimental scale by the Electro Zinc Co. at Welland, Ont., while some work in this line was done at Keokuk, Iowa, and at Bully Hill, Cal., and there were one or two other operations (one of these employing the Isherwood process) that may not yet be mentioned publicly. The work at Welland is unique in that the dissolving of the zinc and the electrolysis of the solution is performed in the same vat, the cathodes being inclosed within canvas bags. All of the other work, so far as I know, is being done on lines similar to those at Anaconda.

Before going any further, let it be well fixed in the mind that the conditions that have existed in the zinc industry during the last year are not only unprecedented but also it is certain that they cannot be otherwise than ephemeral. They have been due to a shortage of metallurgical capacity, not of ore in the least degree, and that shortage is being reduced with extraordinary rapidity. In the meanwhile, however, there has naturally been a huge metallurgical margin—even $60 per ton of ore against a normal of about $15—in the manufacture of common spelter and with such a margin it has been good sense not only to commit metallurgical crimes, but also to institute new processes that would not ordinarily be profitable. In the manufacture of high grade spelter the margin has been much higher, so much so that the possibility of it would two years ago have been considered nothing less than preposterous.

Now, the electrometallurgy of zinc is no new thing. The electrolytic refining of impure spelter was tried on a large scale by Nahnsen in Upper Silesia in the '90s, the hydrometallurgical-electrometallurgical treatment of zinc ore was essayed disastrously by Ashcroft at Cockle Creek, New South Wales, in a works costing about one million dollars. Dr. Hoepfner developed a process that was put into use at Führfort on the Rhine and at the works of Brunner, Mond & Co., at Winnington in England. At the former it was abandoned after a short time; at the latter it has been continued through a long series of years, making a few hundred tons of spelter annually, and is in use at the present time. The electrometallurgy of zinc has therefore a commercial history of respectable antiquity.

In the early days of the art, both commercial and experimental, difficulty was experienced in obtaining dense deposits on the cathodes, spongy zinc being a stumbling block, but while this matter required some study for its mastery, it was manifest that the real difficulties of this process were the getting of zinc into solution rather than out of it, and the large amount of power required for zinc precipitation.

With regard to the former point, I refer to the formation of insoluble ferrite of zinc in roasting, with the consequence of relatively low extraction of zinc. That is experienced in the case of many, perhaps most, ores that it is desired to treat. To illustrate, roasted Joplin blende may be leached with sulphuric acid so as to cause it to give up 97 or 98 per cent of its zinc, the residue being a white silica sand, but nobody wants to treat Joplin ore by a hydrometallurgical process for the reason that it would be less economical than ordinary smelting. On the other hand, certain mixed ores high in iron like those of Leadville, Col., may give up only about 65 per cent of their zinc. So low an extraction would in itself be prohibitive in most circumstances in ordinary times. It is possible that the roasting might be conducted in such a way as to steer clear between the Scylla of zinc ferrite on the one hand and the Charybdis of undecomposed zinc sulphide on the other hand, but that question has not been investigated with definite results, so far as I know. With regard to the high power required for the electrolysis of zinc solutions with insoluble anodes, the expense of it, when imposed upon the cost of roasting, leaching, remelting cathodes, reworking between products, etc., is likely to make the cost of hydrometallurgical-electrometallurgical zinc extraction too high to be ordinarily considered.

I have, therefore, repeatedly expressed the opinion that metallurgical processes of this sort were unlikely to be successful commercially unless: (1) Exceptionally cheap hydroelectric power, such as the $6 or $7 per annual horsepower of Norway and Sweden were available;* or (2) unless use could be made of the anode reaction, such as the

*Compare, however, the figures given by Mr. C. A. Hansen on the results obtained at Bully Hill (this journal, Feb. 1, p. 120).—EDITOR, MET. & CHEM. ENG.

liberation of chlorine by the electrolysis of a chloride solution and the employment of it for some chemical manufacture, as at Winnington, England; or (3) unless certain especially favorable conditions otherwise existed. By the last I mean such things as high grade of the run-of-mine ore, a kind of ore that will give up a high percentage of zinc by lixiviation with sulphuric acid, an ore high in silver, and possibly lead. These points are almost determinative. In the pyrometallurgy of zinc the extraction of silver is, perhaps, about 65 per cent. In the hydrometallurgy of zinc it ought to be upward of 90 per cent, perhaps as high as 95 per cent. The situation with respect to lead is somewhat similar. It is needless to dwell upon the importance of this in the cases of ore exceptionally high in silver.

Now, in the treatment of the Butte ore at Anaconda, about all of the favorable conditions that I have enumerated under the third head exist. The ore raised from the mine is of rather high grade, it is of a character that enables 90 per cent of the zinc, or more, to be extracted by sulphuric acid lixiviation, and as zinc ores go, it is exceptionally high in silver (the concentrated ore going 20 oz. silver per ton, or thereabouts). Moreover, the Anaconda company is introducing zinc extraction in connection with its other great metallurgical work, thus dividing general and administrative expenses, etc. It is able to obtain moderately cheap power at Great Falls, and finally, what is not least in importance, it possesses about the best metallurgical organization of any concern in the United States, and is instituting this new process at a time when there ought to be commercial profit in spite of any imaginable infantile disorders. I am not free to communicate such figures respecting the Anaconda results as I know, but I may say that the Anaconda management is thoroughly aware of the exceptional conditions existing in the zinc industry at present and is nevertheless of the opinion that with its peculiarly favorable circumstances it can continue the production of electrolytic zinc in competition with everybody else in the normal times, or even in the hard times that may be experienced after the termination of the war. The promise of the development of the hydrometallurgy-electrometallurgy of zinc as a commercial art on a large scale has, therefore, already become a prospect. There is to be such an art. The magnitude that it will attain, and its effect upon the zinc industry of the world, remain for the future to tell, but that it is going to have an early and important influence is not to be doubted.

Turning attention to some of the technical features of electrolytic zinc production, the conditions governing the electrolysis of zinc solutions were exhaustively treated by Dr. Victor Engelhardt in a paper read at the first general meeting of the Gesellschaft Deutscher Metalhütten und Bergleute and published in *Metallurgie* a few years ago. A summary of Dr. Engelhardt's conclusions, together with some additional notes, was published by Prof. J. W. Richards in "Transactions of the American Electrochemical Society, XXV," pages 281-290. The ideas of Dr. Engelhardt, who is the chief engineer of the electrochemical division of the Siemens & Halske Company of Berlin, are exemplified in what are called the Siemens & Halske and Isherwood processes. However, in the late development of zinc electrolysis "processes" and patents have played but slight part. With recent experimenters the matter of spongy zinc deposits appear to have been among the least of the difficulties. Mr. Keating succeeded several years ago in depositing smooth, solid zinc on his cathodes at Bully Hill, Cal., while as for Mr. Laist, he accomplished this part of the process as a matter of course, just as simply as if he were depositing copper, the necessary precautions as to purity of solution, etc., being naturally taken.

With regard to the grade of electrolytic zinc, high purity is easily obtained. This is something that is far more under control than in refining by fractional distillation. Lead ought not to go appreciably into solution at all, while iron, copper and cadmium—the other common impurities of spelter—are readily precipitated from the solution. The spelter first made at Anaconda was higher in cadmium than is permitted by the standard specifications for "high-grade." At that time zinc dust, more or less impure, was being used as the precipitant for cadmium. Running the clarified solution through a tube mill filled with zinc balls corrected this, and the grade of the spelter was then raised to upward of 99.9 per cent. Brunner, Mond & Co. have been for many years guaranteeing their electrolytic spelter at 99.95 per cent, and there is no reason why the Anaconda spelter should not be made as good as that.

Is electrolytic zinc extraction going to revolutionize the metallurgy of zinc? Unqualifiedly, no. When the zinc industry returns to its normal status, conditions will be in the main as they were before the war, and the principles that I have previously stated will continue to obtain, with the difference that some people will have learned the details of the art, will have gone through the period of infantile mistakes in a time when almost any mistake was of no great consequence. By that time some of the concerns possessing exceptionally favorable conditions—Anaconda, if any—may be able to continue. Others will not.

However, there are certain new industrial features that can not yet be clearly estimated and may have a modifying effect upon this forecast. One of these relates to the matter of high grade zinc. Previous to the war that class of spelter was produced in limited quantity and sold at a premium over common spelter of about 2½c. per pound. Inventors, promoters and others who talked about making such zinc were discouraged from reckoning upon the premium by the dictum that the market would not take any more than the then supply, which was indeed artificially limited, and that it was unsafe to count on anything but the price for common spelter. During the war high-grade spelter has fetched 40c. per pound, and at times the demand for it has been insatiable. This demand has been especially in connection with the manufacture of ammunition and may be expected to cease with the war, but will the advertising that high-grade spelter has had and the wider knowledge of its peculiar properties that has been acquired give it a more extensive use in the peaceful arts and a maintenance of the premium for it that will be to the advantage of the electrolytic producer? Or, will it become a drug in the market, with entire disappearance of price differential? These are questions that nobody yet knows enough to answer reasonably.

Another new and uncertain factor is the bearing of the flotation process of ore concentration upon the metallurgy of zinc. I think that this had a good deal to do with the institution of the Anaconda work. About all metallurgical work is a sequence of steps of concentration and refining, treating the bulk of the ore by a cheap but wasteful process and delivering a concentrated product to a more costly but less wasteful process. Now, most experimenters in the hydrometallurgy and electrometallurgy of zinc heretofore have contemplated the application of a costly process to the run-of-mine ore. The flotation process has enabled ore to be concentrated at relatively small cost with but slight loss. Let it be observed, therefore, that Mr. Laist is applying his costly process not to run-of-mine ore, but to a flotation concentrate in which about 90 per cent of the zinc is concentrated in about one-fourth of the original weight. This is the new and important feature of recent zinc electrolytic work.

We must let our thoughts run a little further ahead. The treatment of flotation concentrate is one of the present troubles of the zinc smelter, owing to its excessive fineness, which produces difficulties that it would take me too long to describe. Yet the proportion of this class of ore that the zinc smelter is getting is still relatively small. The supply of it is, however, bound to increase, and when it becomes large the troubles of the zinc smelter will really begin. Now the hydrometallurgist will have the same troubles up to and through the roasting of the ore, but he will be free from those that arise in the distillery. In so far he will have an advantage over his brother pyrometallurgist, but whether it will be a weighty advantage I do not venture to offer an opinion.

Another thing that may help the hydrometallurgist is improvement in the method of roasting. Twenty-five years ago he used to talk about sulphate roasting. He did not in practice find the idea to work out as well as he expected. While he might be able to render 40 or 50 per cent of the zinc soluble in water, he found there was too much undecomposed sulhpide left behind after leaching with sulphuric acid. So then he said he would roast the ore, completely leach all the zinc with sulphuric acid and be done with it. To his surprise he found that much of the zinc had been rendered soluble by the formation of zinc ferrite if iron were present in the ore, as was almost always the case. The roasting of ferruginous blende in such a way as to convert all of the zinc into sulphate and oxide, avoiding both sulphite and ferrite, which may perhaps be done by correct control of temperatures, perhaps by some other control, is an interesting subject for investigation. Mr. Laist has given some attention to this by carefully limiting the temperature of his roasting furnace. However, I think that perhaps the danger of ferrite formation is not very great in the case of his ore. Anyway, I know that it is not in roasting some similar ore of Butte without much regard to the matter of temperature.

In view of the very late hour the discussion was very brief. In reply to a question by Dr. Baekeland, Mr. Landis replied that the cost of getting nitrogen gas from liquid air is one of the smallest cost items in their cost sheet.

The Operation of the Blast Furnace

BY J. E. JOHNSON, JR.

(*Concluded from Page 215*)

The Progressive Changes in the Ascending Gas Column

Turning now to the changes in the gas column, we find that these are of three separate kinds, but owing to the fact that the physical state of the gas does not change they are less sharply divided into zones than in the case of the solid and liquid materials. The three kinds of change are chemical, thermal, and physical. That is, change in composition, in temperature, and in pressure and density of the gas.

Considering first the chemical changes we have the blast entering, in coke practice, in a highly heated condition at the tuyeres, and in good practice distributed by their action with approximate uniformity over the tuyere zone from which it rises through the coke column, at first being converted to CO_2, but as it rises from the tuyeres the gas is exposed to an excess of carbon precisely as in a producer bed with the result that the CO_2 quickly breaks down, the additional supply of carbon taking from the CO_2 half its oxygen and reducing the whole to CO. With the blast enters a certain amount of water vapor, and this is instantly dissociated by the incandescent fuel into hydrogen and oxygen, the latter uniting with the fuel exactly as if it entered in the form of oxygen, the hydrogen rising through the lower zones of the furnace as such, but meeting with different fortunes in the upper regions according to the conditions.

We have already seen that the combustion of all the oxygen of the air to CO is complete at the top of the bosh, and as it rises from this point it is progressively exposed to ore containing more and more oxygen, from which the gas progressively removes this element, converting a portion of the CO into CO_2.

It is well to reiterate here, what I have tried to make clear in earlier chapters, that the ratio of CO and CO_2 in the issuing gases does not depend upon any equilibrium diagram no matter how scientifically derived, but upon the simple arithmetical fact that each unit of ore requires for its final reduction and melting in the hearth a certain quantity of hearth heat, for the production of which a certain definite quantity of fuel is necessary, an amount which can easily be calculated if the conditions are given. This fuel is, as we have seen, burned to CO in the hearth, the unit of ore contains a definite quantity of oxygen, and this quantity of oxygen combining with the given quantity of CO produces a mixture of CO and CO_2 of

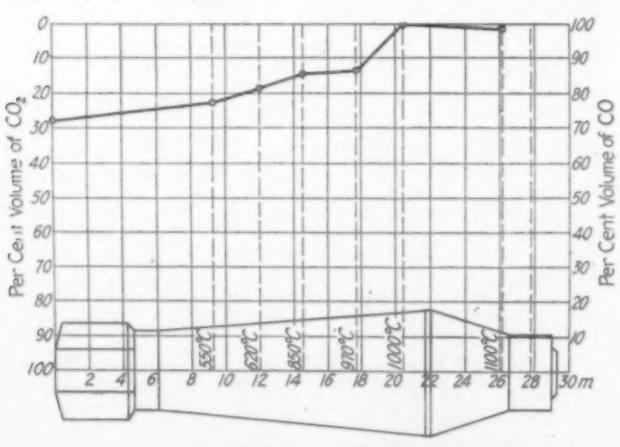


FIG. 1—PERCENTAGE CURVE OF CO_2

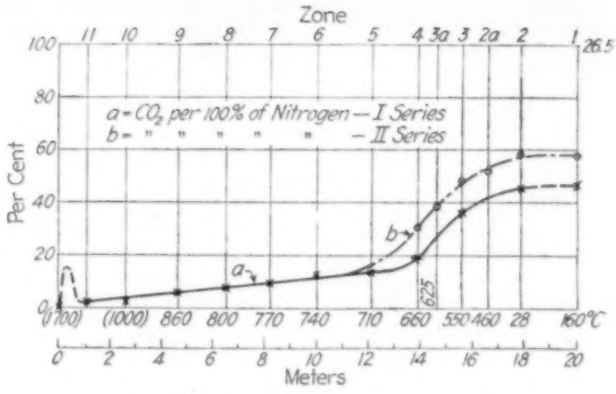


FIG. 2—PERCENTAGE CURVE OF CO_2

a composition depending purely upon chemical arithmetic, at least within limits far beyond those which we have ever reached. This condition is somewhat modified by the amount of solution loss of fuel which occurs, and this does depend, among other factors, upon the relative concentration of the two gases, but it cannot be too strongly emphasized that the arithmetical relation rather than the chemical equilibrium is the predominant factor in determining the ratio of the top gases.

When we reach a certain point in the furnace the rather slow and orderly change of gas composition takes a sudden turn, the percentage of CO_2 increasing quite rapidly, this increase coming from the CO_2 driven off from the limestone by the heat of the furnace exactly as in a lime kiln.

Figs. 1, 2 and 3 are reproduced from *Stahl und Eisen*, Vol. 31, Fig. 1 from an article by W. A. Schlesinger, Figs. 2 and 3 from one by M. Levin and H. Niedt. These are based upon experimental determinations made by sampling the gas at different heights in the furnace through holes drilled in the wall.

Fig. 2 shows the sudden rise of CO_2 quite plainly, Fig. 3 does not show it, although there is an increase in the rate of rise of the curve in one region, and Fig. 1 shows an absolutely uniform rise of CO_2 after a sudden increase just above the top of the bosh. These figures are given because of the scarcity of experimental data of this kind, and because experimental data even though they be not representative of our conditions are better than purely theoretical illustrations.

At the same time these curves are all lacking in a strongly marked feature which I found with unmistakable plainness in the course of some experimental work. This is the fact that when CO_2 is driven off from the limestone it at once attacks the carbon vigorously, and a part of it is reduced back to CO so

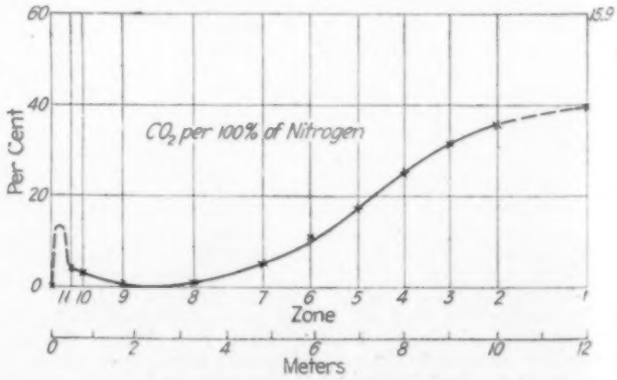


FIG. 3—PERCENTAGE CURVE OF CO_2

that the concentration of CO_2 at the top of the furnace is considerably less than it is at a point somewhat lower down. This fact was determined by running a 6-in. pipe down through the center offtake of a furnace with the Longdale type of top, to a point some 8 or 10 ft. below the stock line, and taking simultaneous samples of the gas discharged through this pipe and that at the top of the furnace. Determinations were made several times, and with a result broadly the same in every case.

This, it must be admitted, is to some extent a contradiction of my statement above that the equilibrium ratio was of minor importance in determining the composition of the top gases, because obviously here we have an established equilibrium disturbed by outside conditions and automatically restoring itself. But my impression is that, as intimated above, this is a matter affecting the solution loss of the coke rather than the equilibrium between the iron ore and the gas composition. It is, moreover, probable that this condition was much more marked in these two furnaces than in many others for three reasons, that the ore was lean, and the quantity of limestone charged, and of CO_2 disengaged, therefore very large; that the top of the furnace was quite hot, and that the coke was distinctly of a soft and, therefore, readily soluble variety. There can, however, be no doubt that this tendency exists. I believe that the same result has been obtained by other observers sending pipes down from the top of the furnace, but I have no data as to these tests.

TEMPERATURE CHANGES IN THE ASCENDING GAS COLUMN

Figs. 1, 2 and 3 each show a scale of temperatures at different elevations taken through the same observation holes as the gas analyses, but I am unable to accept the temperature given for a point just above the tuyere plane, 2012 deg., as correct, because this is the hottest zone of the furnace and must be at least as hot as the issuing iron and slag which in ordinary coke practice are from 2650 deg. to 2850 deg.

This temperature has been obtained by many hundreds of direct pyrometric observations on issuing iron and slag at several blast furnaces. This is a line of work which has been too little followed, partly because of the lack, until very recent years, of pyrometers of sufficient accuracy to inspire any respect, and partly because of indifference on the part of furnacemen. It is gratifying to note that at the extensive test of titaniferous ore at Fort Henry a pyrometer expert was employed to make observations of the temperature of running iron and cinder, and it is a matter of much satisfaction to the writer that the results of these accurate tests indicated a temperature of about 2800 deg. on this experimental run using all magnetic ore (which requires more fuel and a hotter hearth than softer ores), as against the figure of 2750 deg. obtained by me as the result of many thousands of observations with a much less accurate instrument, a number of years ago, on a furnace working a more reducible, though leaner ore, and almost certainly running with a somewhat colder hearth.

Another reason for mistrusting the data given in Figs. 1 to 3, particularly Fig. 1, is that the drop in temperature from a point just above the tuyeres to the top of the bosh is given as only 100 deg. C. or 180 deg. Fahr., whereas all the facts of practice, above all observations on blown-out furnaces, indicate by the condition of the walls at these points that a far greater difference in temperature between them has existed. For instance, when iron-pipe cooling blocks are used, the cast iron around the wrought pipes is

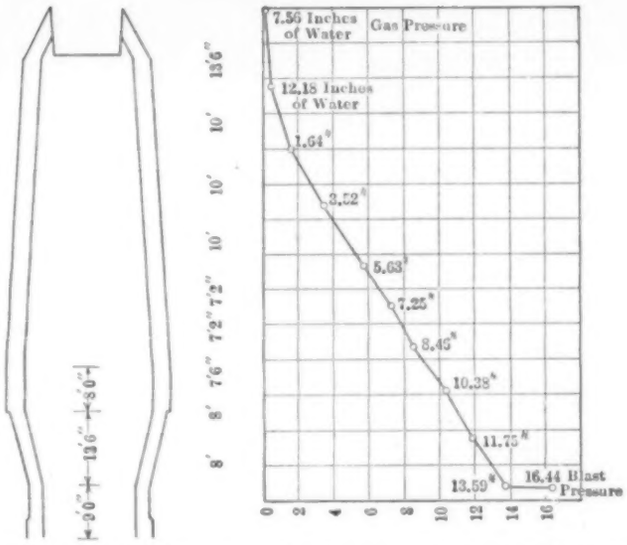


FIG. 4—PRESSURE TEST ON NO. 4 FURNACE AVERAGE OF 25 READINGS

frequently entirely melted away so that the pipe runs naked in the furnace, in and just above the tuyere plane, while precisely similar blocks at a plane 10 or 12 ft. above are not only perfect in shape, but frequently look when they are taken out at the end of the blast as though they had never been used.

From the top of the bosh upward we have a practically uniform drop in temperature to that at which the gas is discharged, this depending as shown in the last chapter upon the thermal conditions of the operation, the total drop being roughly proportional to the iron produced per ton of fuel.

CHANGES IN THE GAS PRESSURE

Here fortunately all speculation can be laid aside, for owing to the kindness of Mr. Reese I am able to present a diagram, Fig. 4, giving the results of 85 sets of observations of pressure made at holes cut at different levels in one of his furnaces.

There will be seen first a quick drop from the tuyere pressure. This is the penetration drop described in a previous article. From this point on we have a practically straight line drop to a point quite close to the top when the rate of drop slows down, and the curve becomes concave to its base line. This is not due to any change in the law of pressure-drop but merely to the fact that the top of the stock is not a level plane but a conical crater, probably 8 or 9 ft. in depth. The gas pressure begins to be relieved at the bottom of this in the center, but, of course, there is still some resistance and therefore some pressure at the circumference of the furnace at any point below the top of the crater, hence the tapering off in the rate of the drop.

These observations were all made when this furnace was working regularly and properly, but Mr. Reese has also had observations made when the furnace was working irregularly, shown in Fig. 5, and these are equally instructive, if not more so. It will be seen that there are regions in which the pressure drops very rapidly indicating a decided constriction at this point followed by a rate of drop slower than the average, indicating that above the obstruction the gas had ample room to slow down and so reduce the friction drop.

Whether the sudden pressure drop was due to abnormal changes in the charge and produced the irregular working, or whether a partly scaffolded condition produced the sudden pressure drops it is virtually impos-

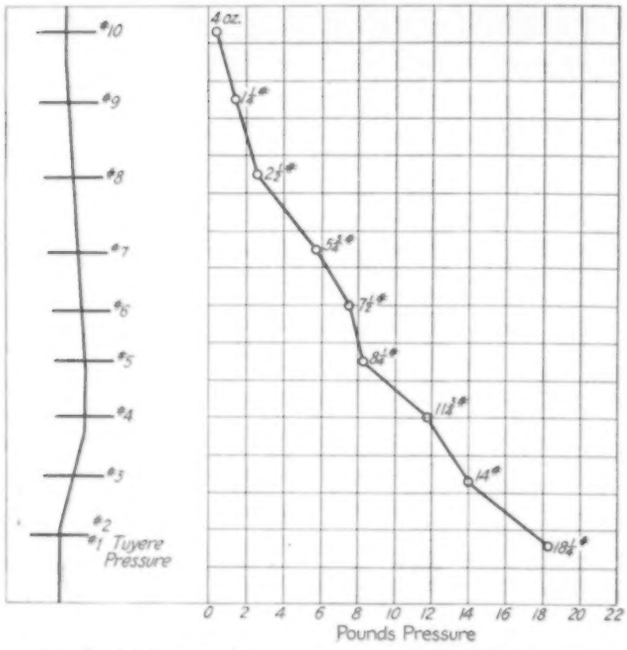


FIG. 5—PRESSURE OF FURNACE MOVING IRREGULARLY

sible to say, but bearing in mind what has been said about the importance of uniform flow of gas, from the practical point of view in cutting down dust losses and the like, the very serious results which must follow from these irregular pressure conditions become obvious, and it is a matter of no surprise that the furnace working under these conditions should produce unsatisfactory results. On the other hand, the extremely smooth curve was obtained as the result of many observations on a smooth working furnace, and its regularity (which must be a matter of surprise to those accustomed to the many minor changes which even a good working furnace makes) indicates that a uniform and regular pressure drop is both the condition and the product of smooth and regular working.

These extremely valuable and interesting results have never before been published and I feel that Mr. Reese has placed not only me but the other members of the profession under a lasting debt of gratitude by so generously allowing their publication here.

SHAPE OF PRESSURE CURVE

The rate at which the pressure drops is a matter of some interest. The shape of the curve of decreasing pressure in a pipe line given by the formula quoted in the last chapter, and established by experiment, is a parabola, the pressure falling slowly at first and more rapidly afterward, just as a horizontally thrown ball does under the influence of gravity. The same should be true of the curve of pressure drop in the furnace because in it as in the other the difference of the squares of the pressures is proportional to the resistance.

Mr. Reese's curve is almost exactly a straight line. One cannot help but wonder if a slight increase in the bosh diameter yielding a lower rate of pressure drop at first, and a proportionately somewhat more rapid one later, would not give a closer approximation to the theoretical parabola, which would correspond with a more nearly uniform velocity, and might easily result in slightly better working for reasons pointed out in the last article.

The spring meeting of the American Chemical Society will be held at Urbana, Ill., from April 18 to 21. That of the American Electrochemical Society at Washington, D. C., from April 27 to 29.

Work on the Federal Trade Commission

The value of technical associations to technical men are well known to most of our readers. That business associations are equally as valuable to business men was brought out in an address by EDWARD N. HURLEY, vice-chairman of the Federal Trade Commission, before the annual meeting of the Rubber Club of America, in New York, Feb. 2, 1916. Mr. Hurley discussed the work of the Federal Trade Commission and showed how the Government could assist business if it had the necessary data. The commission is constantly receiving requests for information on how to improve conditions, and to meet unfair competition. Upon investigation the Commission found that detailed data was nowhere available which would enable them to pass on the underlying difficulties. The Commission in order to co-operate is preparing a few simple questions pertaining to their industries which they will submit to the business men in a few weeks.

Mr. Hurley said the collecting of statistical data could best be done by the Government on account of its facilities and the confidence felt in it by business men. There are about 250,000 business corporations in the country and over 100,000 of these report no net income whatever. In addition 90,000 make less than $5,000 a year, while only 60,000 make $5,000 a year or over. In tabulating data on the successful corporations the Commission found that out of 66,000, 30,000 charged off no depreciation whatever and this demonstrated the need of a thorough study of our industries and a necessity for better accounting methods. Price cutting and demoralization of many industries has been done without an adequate knowledge of cost. The Commission hopes to improve conditions by indorsing standard systems of bookkeeping and cost accounting and by assisting in devising standard systems either at the requests of individual concerns or representative associations.

In the field of standardizing products, processes, and raw materials much has already been accomplished. Many industries have adopted specifications to which practically the whole industry conforms. Much of all this has been brought about by associations, but we have made only a beginning. In Germany every important industry is organized into trade associations and 85 per cent of the manufacturers are represented. The old adage "In unity there is strength" is put into practice, and has proved to be the backbone of Germany's industrial and commercial achievements. More than 600 independent associations of manufacturers, producers and merchants are in existence there.

Coming Society Meetings

The American Institute of Electrical Engineers has extended a courteous invitation to the New York Section of the American Electrochemical Society for a meeting on "corrosion" (with special reference to the electrolytic corrosion of underground structures). The meeting will be held on the evening of March 10 in the lecture hall of the United Engineering Societies Building, 29 West Thirty-ninth Street, New York. The two principal speakers will be Dr. Burton McCollum of the Bureau of Standards, Washington, D. C. (representing the A. I. E. E.) and Professor William H. Walker, of the Massachusetts Institute of Technology (representing the A. E. S.).

A meeting of the New York Section of the American Chemical Society will be held on the evening of March 10, in Rumford Hall, Chemists' Club. At this meeting the Nichols medal will be awarded.

A meeting of the New York Section of the Society of Chemical Industry is announced for March 24, to be held in Rumford Hall, Chemists' Club.

The Bureau of Mines Work on Manufacture of Gasoline and Benzene-Toluene from Petroleum

The researches of Dr. W. F. Rittman of the Bureau of Mines, on the production of gasoline, benzene, and toluene from petroleum and other oils have deservedly attracted such a widespread attention that the first complete official publication of the results of this whole series of researches will be exceedingly welcome. It is being published as Bureau of Mines Bulletin No. 114, and is entitled *"Manufacture of Gasoline and Benzene-Toluene from Petroleum and other Hydrocarbons,"* by **W. F. Rittman, C. B. Dutton** and **E. W. Dean,** with a bibliography compiled by **M. S. Howard.** From press sheets of this Bulletin the following is taken.

In the preface to the Bulletin some interesting figures on gasoline production are given, taken from a report made by the Secretary of the Interior to the U. S. Senate under date of Feb. 21, 1916, and published as Senate Document 310.

The estimated production of gasoline in the United States for 1915 was 41,600,000 barrels, the amount exported 6,500,000 barrels, leaving 35,100,000 barrels for domestic consumption. The consumption is estimated to have been 25 per cent greater than in 1914. The Secretary of the Interior says the increased cost of gasoline is due to increased domestic consumption, increased exports, decreased production of crude oil containing a large percentage of gasoline, the increase in the price of crude oil and financial influences. The preface states that on Feb. 1, 1916, seven refineries, in six States were installing plants for the Rittman gasoline process, and that benzene and toluene were being produced in large quantities by the other process.

Part I of the Bulletin which comprises 126 pages is entitled "The Cracking of Oils: Principles Involved and Methods of Treating Recovered Products." After taking up the consideration of the present demand for gasoline a historical review of older patented cracking processes is given. This is followed by general considerations on the uses of benzene and toluene and other aromatic hydrocarbons in dyes and explosives and a review of patented processes for their production from petroleum. A complete account of the laboratory experiments made in Columbia University, which led up to the commercial development of the processes is then given. The results of the experiments led to the following conclusions:

In procuring the desired products of the cracking reaction, the physical and chemical properties of an original oil are of secondary importance compared with the influence of temperature, pressure, time, and concentration.

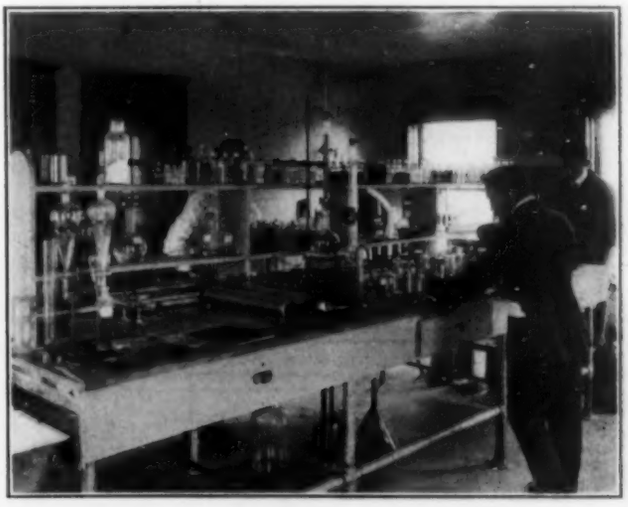
Under like conditions, practically identical results have been obtained from five different oils, and the differences reported may be attributed, in part, as much to variation in rate of reaction as to the actual production of dissimilar equilibrium products. One exception noted relates to the production of carbon, a residual product, the formation of which seems to be proportional to the quantity contained in the original oil. Viscosities and specific gravities of the oils obtained show in some measure the influence of the properties of the original oils, but the differences are only slight and can perhaps be explained by the system not having been allowed to reach complete equilibrium.

The experiments have indicated the commercial possibilities and advantages of hydrocarbon reactions carried out in a cracking chamber composed of a vertically arranged tube, when the products to be treated are in a gaseous state and are cracked in an atmosphere of decomposition products. The results obtained with large-scale equipment, subsequently described, have demonstrated the correctness of these conclusions.

In connection with these experiments it was also proved that it was possible to make trinitrotoluene from toluene derived from petroleum with as high a melting point and as pure as that from toluene derived from other sources. The method developed was a modification of the two-stage process, producing first mononitrololuene with subsequent purification and conversion into the trinitro derivative.

Experiments on the cracking of pure hydrocarbons followed by a confirmatory test using petroleum led to the following conclusions: From cymene it is possible to produce by "cracking" all the other hydrocarbons of the series, such as xylene, toluene, benzene, naphthalene,

GENERAL VIEW OF THE IRVINE PLANT, AETNA CHEMICAL COMPANY, PITTSBURGH, PA.



LABORATORY AT DEVELOPMENT PLANT, SHOWING TYPE OF DISTILLATION APPARATUS USED IN TESTING CRACKED OIL

and anthracene. From xylene results toluene, benzene, naphthalene and anthracene, but no cymene. Toluene yields benzene, naphthalene and anthracene, but no cymene and no xylene. Benzene goes to naphthalene and anthracene, but not to any of its higher homologues. From naphthalene anthracene is readily obtainable, but none of the monocyclic hydrocarbons, benzene, toluene, xylene and cymene is produced. Anthracene yields no naphthalene, but goes to tarry matter, carbon and gas.

Likewise it appears that the formation of higher benzene homologues is favored by less strenuous conditions of cracking than constitute an optimum for benzene. Polycyclic hydrocarbons are shown to be decomposition products of monocyclic hydrocarbons, as production of the latter falls off under cracking conditions that favor the formation of such typical compounds as naphthalene and anthracene.

On the basis of the evidence at hand it seems justifiable to state that the course of the cracking reaction in the aromatic series may be indicated as follows and that practically no reverse action occurs.

Higher benzene homologues ⇄ lower benzene homologues ⇄ benzene ⇄ (diphenyl) ⇄ naphthalene ⇄ anthracene ⇄ carbon and gas.

APPLICATION TO OTHER FIELDS OF PRINCIPLES ESTABLISHED BY HYDROCARBON REACTIONS

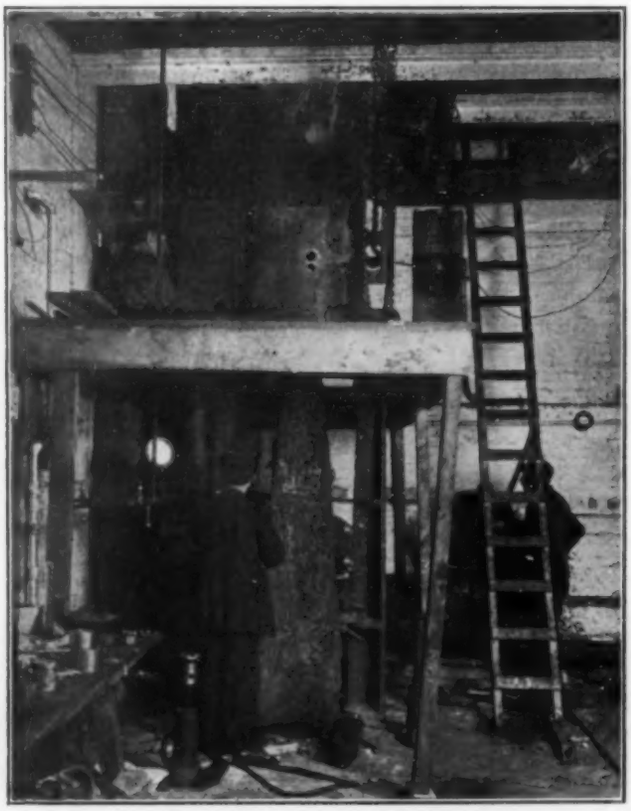
The technical and industrial importance of these different reactions is much greater than their application to the treatment of petroleum alone would indicate. The principles involved are equally applicable to the treatment of coal, lignite, peat, bitumen, or any other substance capable of yielding liquid hydrocarbons. In fact, the field for application of these principles is even greater as regards these other substances because of their greater extent and production. The output of petroleum in the United States, although 65 per cent of that of the whole world, is decidedly secondary, on the basis of volume and tonnage, to that of solid fuels, indicating at once the tremendous possibilities in the production of tar and other hydrocarbons from coal and the other materials enumerated.

In view of the widely varying percentages of the different aromatic hydrocarbons obtainable from a crude oil, and in view of the course of reactions among aromatic hydrocarbons, a most significant feature is that there are present in the tars resulting from most present-day distillations of coal a small percentage of low-boiling aromatic hydrocarbons, such as benzene and toluene, and a very large percentage of aromatic hydrocarbons of large molecular weight such as naphthalene and anthracene. The latter undoubtedly are formed in some stage of the operation from monocyclic aromatic hydrocarbons. In practically all coal tars there is less than one part of toluene to three parts benzene. It is furthermore common information that naphthalene, methyl-naphthalenes, methyl-anthracenes, anthracenes, etc., are present in large proportions. In the light of the investigations reported, which unquestionably indicate the course of reaction to be first in the formation of the higher members of the benzene series, then progressively to the formation of toluene, benzene, naphthalene, anthracene, carbon and gas, it is to be concluded that practically every present coal-distillation process carries the cracking to the point of ruinous decomposition of benzene and toluene in the formation of the higher boiling aromatics. The Bureau of Mines is at present investigating this feature.

LARGE-SCALE WORK

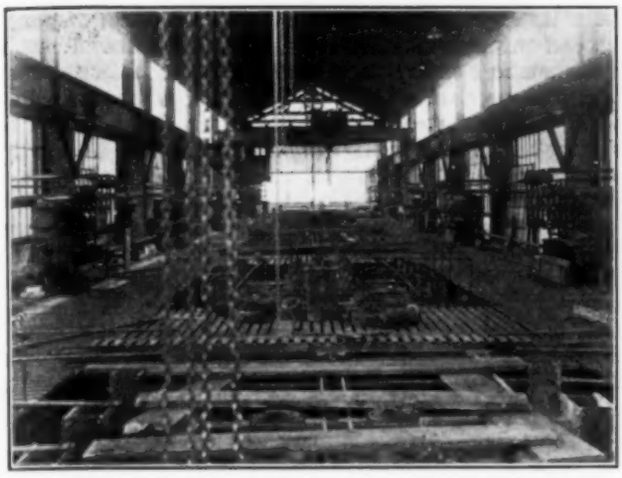
The second part of the Bulletin comprising 81 pages deals with the large-scale development of the benzene-toluene and gasoline processes. The following is abstracted from the second part:

On March 9, 1915, a contract was entered into with the Aetna Explosives Company, who agreed to spend

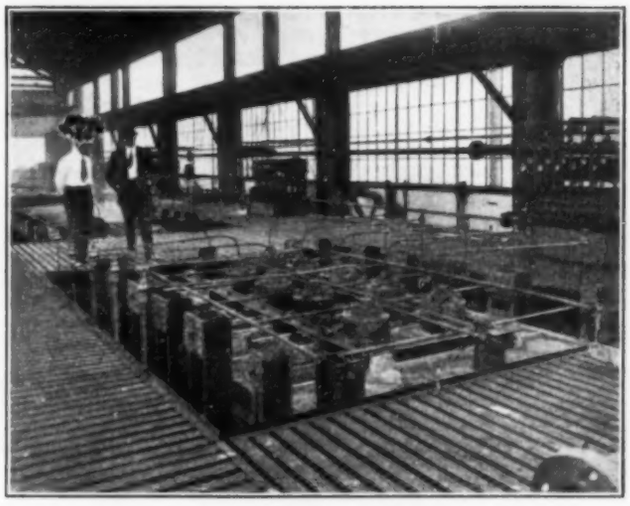


CHARACTER OF SMALL SINGLE-TUBE FURNACES; CONDENSER IS SHOWN IN LEFT FOREGROUND

GROUND FLOOR VIEW OF FURNACE BUILDING, SHOWING ARRANGEMENT AND BUILDING OF FURNACES NOT COMPLETED, AETNA CHEMICAL COMPANY



GENERAL VIEW FROM BALCONY OF OIL PUMPS AND PRESSURE RELEASE VALVES



ARRANGEMENT OF OIL FEED INTO CRACKING TUBES

$200,000 in the development of the process. Applications for patents on the processes were filed in March, 1915, and it has been decided to have the patents administered by the Secretary of the Interior who will issue licenses to those desiring to use the processes. No royalty or other monetary payments will be required. Although the use of the processes is to be free of charge to all citizens of the United States, it has been considered necessary for the protection of the basic patents, that licensees shall assign to the Secretary of the Interior, as trustee, all patentable improvements, relating to the processes, that may be developed by them during the employment of the process. A provisional form of license has been adopted while the patents are pending. For any information as to licenses application should be made to the Director of the Bureau of Mines, Washington, D. C.

Large-Scale Development of Benzene-Toluene Process

Under the terms of the agreement with the Aetna Explosives Company the work incident to the development of the benzene-toluene process on a scale of commercial magnitude was begun at Pittsburgh, Pa. The engineering firm of Mackintosh, Hemphill & Co. of Pittsburgh, Pa., was retained by the Aetna company for the purpose of developing the mechanical apparatus necessary for the large-scale utilization of the process. Mr. C. C. Stutz was placed by this company in direct charge of engineering matters, under the general supervision of Dr. F. L. Slocum, as representative of the Aetna interests.

EXPERIMENTS WITH VARIOUS SIZES OF TUBES

The original apparatus which was used in the laboratory experiments consisted of a tube 1½ in. in diameter by 3 ft. in length. By many steps it was found that a 6-in. by 10-ft. tube was satisfactory and in harmony with those obtained with other tubes. It was proved that the reaction could be carried on as successfully in a tube of this size as in the much smaller tubes which were first used. But it was evident that the maximum size of furnace body had not yet been found, which suggested the advisability of experimenting with a tube of larger capacity, and tubes up to 14 ft. in length were tried.

From this whole series of experiments it was evident that conversion into low-boiling aromatic hydrocarbons will take place in tubes of any size from 1½ in. by 3 ft. to 8 in. by 14 ft.

Reactions occur as readily in one size of tube as another. The variation in extent of heating surface, however, makes it necessary properly to adjust conditions of temperature, pressure and rate of feed in order to obtain maximum conversion and minimum waste in the form of ultimate decomposition products. The desirable combination of conditions must be experimentally determined for each oil used as original material. It was found that for an 8-in. diameter 14 ft. exceeded the optimum length which could be used, because of the mechanical rather than chemical disadvantages. Likewise it was found that a 7-ft. tube was too short, not because of chemical or mechanical difficulties, but on account of the commercial factor of greatly decreased capacity. The most efficient length for tubes 8 in. in diameter was determined to be 10 ft. (for the heated zone).

A long series of experiments was made with a view of using multiple-tube furnaces instead of single tubes.

Observations of the results obtained in a single-tube furnace as compared with those obtained in 10-tube furnaces demonstrated the superiority of the single-tube over the multiple-tube arrangement.

No difficulty was experienced in maintaining temperature control over the single tubes, whereas it was a constant problem to obtain anything like uniformity of heating conditions with the multiple-tube furnace. To get a uniform heat over a small area of the tube it must be heated on more than one side by burners near one plane. This is not possible in the multiple-tube furnace, but is easy of accomplishment in the single-tube type. One side of the tube in the multiple furnace often becomes too hot and the other side too cold. This would not be the case with the smaller installation.

Separate compartments for each tube would, it is believed, be as satisfactory as single-tube furnaces if sufficient combustion space were allowed. The cost of construction would naturally be less if a number of these compartments were constructed as a unit. It is not recommended, however, that more than four such compartments be arranged in a single unit.

Another recommendation in favor of the single tube is the fact that accurate observation of heating conditions is permitted, which is impossible in the multiple type. With the single-tube furnaces a proportionally much larger combustion space can readily be obtained. The larger combustion space will permit a better mixture of the gas and air and will tend to give more uniform heat conditions, owing to the greater distance the products of combustion must travel before reaching the

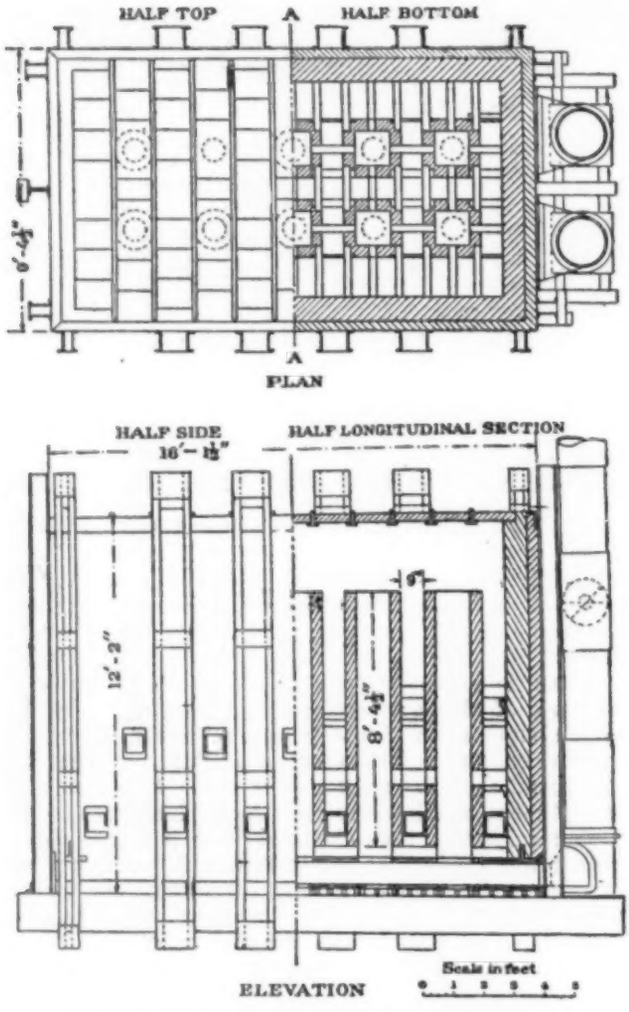


FIG. 1—PLAN AND ELEVATION OF FURNACE

tubes. An outer combustion chamber in which combustion takes place before the gases enter the furnace chamber in which the single tube is set would enable the brickwork in the interior of the multiple furnaces to be dispensed with without any change in the results.

Independent operation of the tubes would permit a tube to be removed or replaced without interfering with the operation of the other tubes. This is difficult in the case of a nest of tubes in a multiple furnace.

Description of Aetna Plant

The details of the furnace construction of the Aetna plant as finally built are given in Figs. 1 and 2, together with the general dimensions of the furnace. The photographs show various parts of the plant.

The furnace proper consists of an outer shell of common brick, lined with a single thickness of standard firebrick. The over-all dimensions of the 10-tube furnace are approximately as follows: Height 12 ft. 5 in., clearance between top and bottom plates 11 ft.; length of sides 16 ft. 1½ in, clearance between inner walls 13 ft. 10½ in., and width 9 ft. 4½ in., clearance between side walls 7 ft. 1½ in. Twenty-two gas burners are used for heating each furnace. Any common type of gas burner of sufficient capacity may be used. The consumption of gas per tube averages about 300 cu. ft. per hour with the present installation, which has not been operated with particular regard to economic heating.

The interior of the furnace is filled with a checkerwork of firebrick. The gaseous products of combustion pass through a baffle arrangement from the gas ports, ascend through the checkerwork and are drawn inside the chambers of firebrick in which the tubes are placed. From these chambers the gases pass out through two flues at the bottom of the furnace shell and are discharged into the open air through stacks 18 in. in diameter placed at one end of the furnace. The flues are so arranged that the products of combustion of the eleven burners on one side of the furnace pass out through an individual stack. The brick shell of the furnace is strengthened by five steel buckstays on each side and three on each end, these stays being approximately 15 ft. 8 in. high and 8 in. wide. The tops of the stays are connected with tie-rods so as to give greater stability to the furnace. The burners of the upper row are placed at a height of 3½ ft. above the heater platform. It has been found necessary to have a double set of burners in order to supply the additional heat required to maintain the tubes at the desired temperature.

The furnaces are set at a height of 10½ ft. above the ground, and rest on 16-in. I-beams, supported by 8-in. I-beams. The furnaces were thus elevated because it was necessary to place carbon receptacles immediately under the bottom of the tubes, and to rotate the stirring rod from below. The carbon receptacles and the stirring-rod drive rest on concrete foundations.

OIL-FEEDING EQUIPMENT

The general arrangement of the oil feed to the tubes is shown by Fig. 3, which is a sketch of a furnace and its connections. The oil is pumped to the supply tanks, which feed the five tubes on each side of the furnace

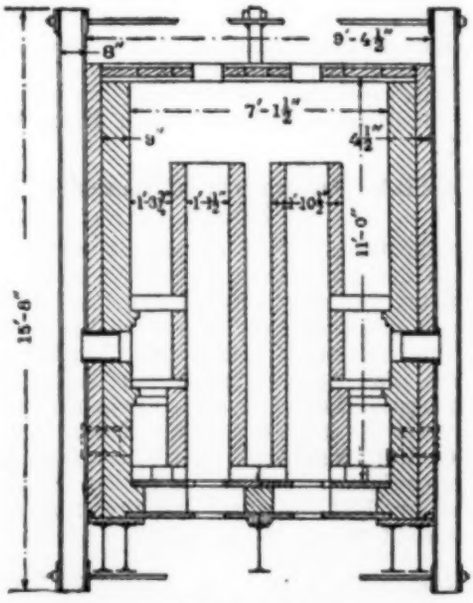


FIG. 2—CROSS-SECTION AA OF FURNACE

and is forced into the tubes by means of triplex pumps, one pump being supplied for each tube.

The oil delivered to each tube by a separate pump traverses a pipe line which is suspended below the upper floor, and thence passes through a needle valve into the top of the tube. The pumps are so constructed that each pump can be calibrated to give any desired rate of flow. The needle valve, which is shown in the foreground, permits independent control of the rate at which the oil is fed into the tube, and enables the oil supply to be immediately cut off in case of accident happening to the tube.

The installation of separate pumps was considered necessary in order to have each tube operated as a

separate unit, notwithstanding the fact that ten tubes were incased in a single furnace.

In the system as installed each tube may be regarded as a separate unit, having no connection with the operation of the other tubes. This type of installation has enabled the reactions occurring in the individual tubes to be carefully studied and has given valuable data which it would be impossible to obtain if the products of all the tubes passed into a single condenser and if a common header were used for supplying oil to all of the tubes.

The individual pumps have served their purpose, but it is not recommended that such a system be used in a new installation. The piping system was so arranged that when the pressure in the tube exceeded the predetermined mark the oil delivered by the pump would be by-passed back into the feed tank.

At first oil meters for measuring the supply fed to each tube were not used, but it was found that the amounts of oil fed into the different tubes varied widely.

The use of meters has been adopted in order to determine accurately the amount of oil passing into the individual tubes, a meter being installed in each feed line. It has been found that through the use of meters better control and regulation of temperature can be obtained than would be otherwise possible, as the rate of feed can be accurately adjusted to conditions existing in the furnace. It is recommended that oil meters be used in any new installation, as the individual cost of the meters is small (approximately $8 each) and the benefits obtained are more than commensurate.

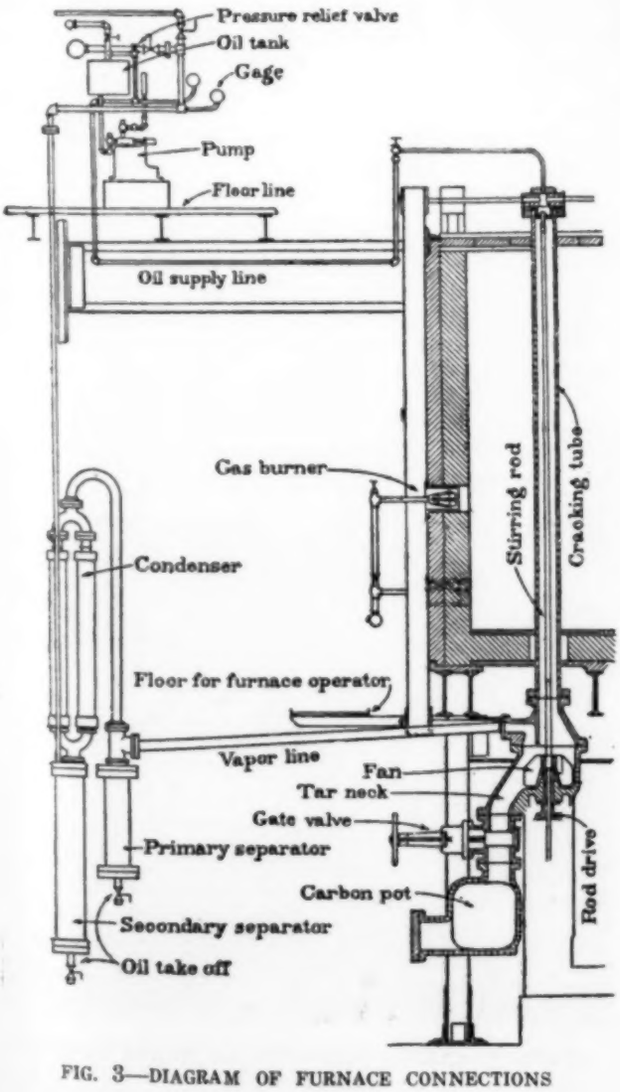
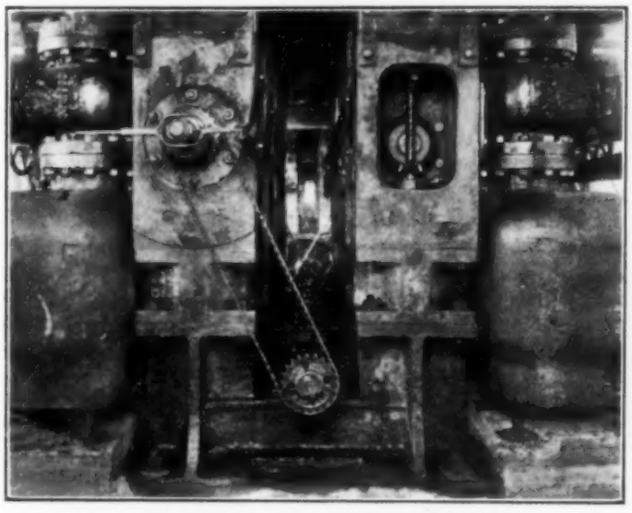


FIG. 3—DIAGRAM OF FURNACE CONNECTIONS

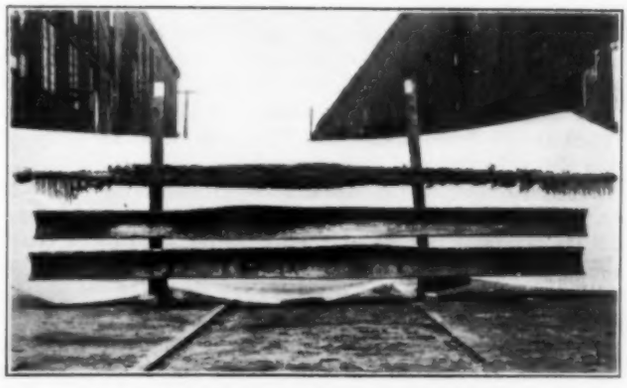
APPARATUS FOR REMOVING DEPOSITED CARBON

The most serious problem that was faced at the outset of operations was the removal of carbon formed on the walls of the tubes. Carbon incrusted on the tube walls acts as an insulator and interferes seriously with the transmission of heat from the furnace to the vaporized oil; also the gradual accretion of carbon diminishes the size of the reaction chamber until the tube becomes entirely choked, which necessitates shutting down the furnace to remove the deposit.

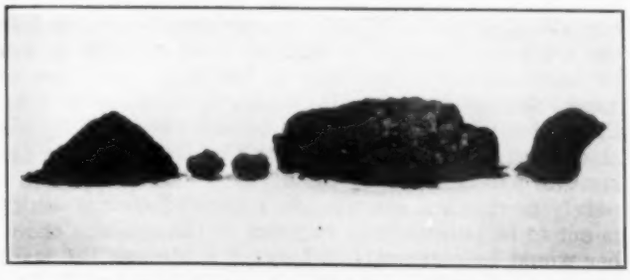
The use of cracking chambers of so large an internal diameter as 8 in. introduces another factor which makes it desirable to use stirrers. In order to heat gases in



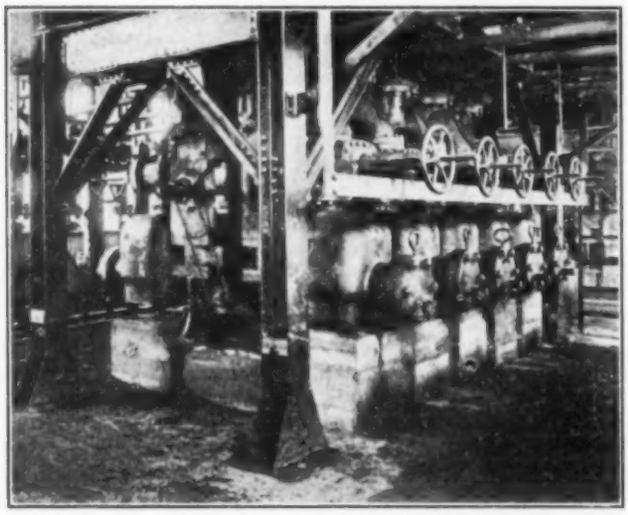
DETAILS OF STIRRING-ROD DRIVE



CARBON ON THE STIRRING RODS, OF HISTORICAL INTEREST ONLY. NOW PREVENTED BY IMPROVEMENTS



CHARACTER OF CARBON FORMED IN OPERATION OF BENZENE-TOLUENE PROCESS. THIS IS THE CHARACTER OF COKE THAT RETARDED OPERATIONS IN THE EARLY STAGES OF DEVELOPMENT OF THE PROCESS



TAR NECKS AND CARBON POTS, SHOWING ALSO ARRANGEMENT OF GATE VALVES

the axis of an 8-in. cylinder to any desired temperature a considerably higher temperature must be maintained at the periphery of the cylinder. One of the advantages of the use of the stirring rod is, therefore, that it makes the cracking chamber annular. Also the stirring action of the rods and chains tends to promote transverse circulation of the gases, which helps to equalize the temperatures.

The use of stirring rods was decided on after careful weighing of the probable advantages of a number of possible devices.

It is apparent that if the rods are continuously rotated in a given direction no means is afforded for cleaning the rod and the chain attached thereto, so that carbon will collect until the accumulation extends to the wall of the tube. The presence of carbon on the surface of the rods and on the chain itself does not, however, interfere with the operation of the apparatus until the amount becomes sufficient to impede the movement of gases through the chamber. When this point is reached the flow of oil into the tube must be stopped and the rod removed and cleaned.

At the outset a rod could be operated only 10 to 24 hr., when the amount of carbon deposition would compel its removal. It has been found possible to increase the length of service to anywhere from 7 to 10 days, with occasional runs of even longer duration.

The use of a rotating rod with wiping chains attached has demonstrated that it will keep the walls of the tubes free from carbon. With the improvements in the construction of this rod which experience has shown to be advisable, and with uniform heat control, it is believed that this type of cleaner can be used with satisfactory results. The great objection, however, to any cleaning device which is permanently retained in the cracking chamber is the fact that although it can be made to clean the walls of the tube there are no means for cleaning it. It is only a question of time, therefore, which in this case means days, before the amount of carbon built up is such as to necessitate the removal and cleaning of the device. Therefore, from a purely mechanical standpoint, a type of cleaner which is not to be permanently retained in the reaction chamber would be more satisfactory, if it cleaned the walls of the chamber equally well. It is entirely possible that a type of plunger cleaner will be found to accomplish this result and obviate the fundamental objection to the use of any intermittent cleaning device, which is the difficulty in obtaining a continuous oil feed and maintaining uniform conditions of operation. But a plunger cleaner head would be more costly to install and would necessitate detachment whenever a tube was to be removed or its condition examined. Likewise the advantages that accrue from throwing the gases against the walls of the tube would, of course, be largely lost with plungers.

CARBON POTS AND TAR NECKS

The tar neck, so-called, is attached to the bottom of the tube by a flanged head, which is bolted to the corresponding flange attached to the tube. The fixed and the condensable gases, and the carbon which has been removed from the walls of the tube by the mechanical stirrer, pass downward into the tar neck or chamber.

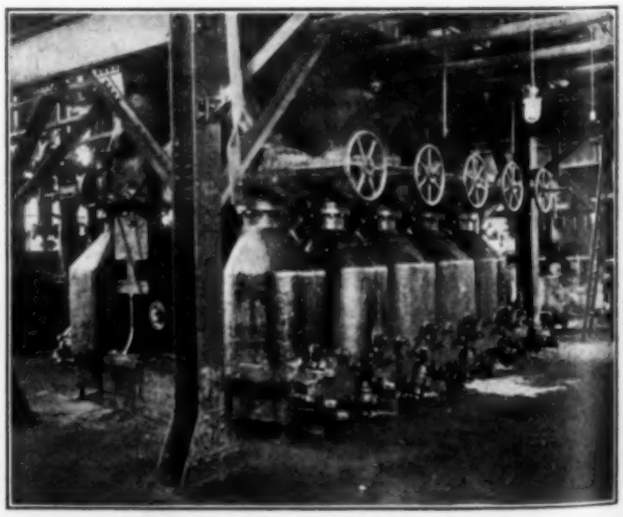
A baffle wall or curtain in the upper part of the chamber around and below which the gases must pass, in order to enter the vapor line leading to the condenser, tends to prevent a large percentage of free carbon from being mechanically carried over with the gases into the condenser. The greater specific gravity of the carbon and pitch causes them to settle rapidly to the bottom of the chamber. (See Fig. 3, p. 273.)

A fan is attached to the vertical shaft which engages with the stirring rod, and is continuously rotated during the progress of a run in order to keep the stirring-rod bearings from being clogged. The action of the fan has a slight tendency also to draw the gases down from the reaction chamber and into the tar neck. The gases, however, being lighter than the heavy pitch and carbon formed, will rise and pass out through the vapor line, leaving the heavy tars and carbon behind.

Carbon receptacles such as those here depicted have the disadvantage of limited capacity. It has been the practice to release the pressure from the tube and to suspend operations while the carbon and pitch were being removed from the carbon receptacle. The duration of the run was fixed accordingly by the capacity of the carbon pot.

The results of the large-scale operations have shown that such massive equipment is not essential. However, this fact could not be predetermined, and it is to the credit of those responsible for the installation that safety has been the first consideration throughout the entire process of development.

The change in the character of carbon formed in the tube from a dense hard coke to a soft flaky carbon, or a heavy viscous tar, has also tended to make the use of large castings unnecessary in the future. If a clean



ENLARGED CARBON POTS USED IN NEWER TYPE OF INSTALLATION

oil is used, such as the distillate to which frequent reference has been made, there is every reason to believe that in place of individual carbon receptacles the tar and carbon can be run from the tar neck direct into a common header and discharged from there into a suitable receiving tank. In fact, provision to this end is now being made at the development plant. If the residuum of recovered oil above the 175 deg. C. cut, or the liquid product from the condenser, is pumped through a suitable opening in the tar neck, there should be no difficulty in causing the carbon and pitch to flow freely through the header. The oil so used can be recovered readily.

The soft flaky carbon is the kind that is formed when proper tube temperatures are maintained throughout a run on Oklahoma crude oil. This soft carbon is usually accompanied by a heavy tar sludge, which is not generally as viscous as that shown in the illustration. Coke is formed when excessive furnace heating occurs. With careful regulation of burners very little of this coke will be produced. The carbon constitutes a valuable by-product and is adapted to a wide variety of industrial uses. It is worth from 1 cent per pound upward, depending on its condition and relative freedom from metallic oxides.

CONDENSERS

At the outset of the experiments it was felt desirable, as previously mentioned, to have each tube operated as a separate unit, thus making it a complete system in itself. This necessitated the use of an individual condenser for each tube. If this plan had not been followed a study of the conversion results in the separate tubes of a single furnace would have been out of the question.

In all new processes a great deal of the equipment considered necessary at the outset can be dispensed with subsequently. This is the case with the individual condensers. Fig. 4 gives details of the condenser construction.

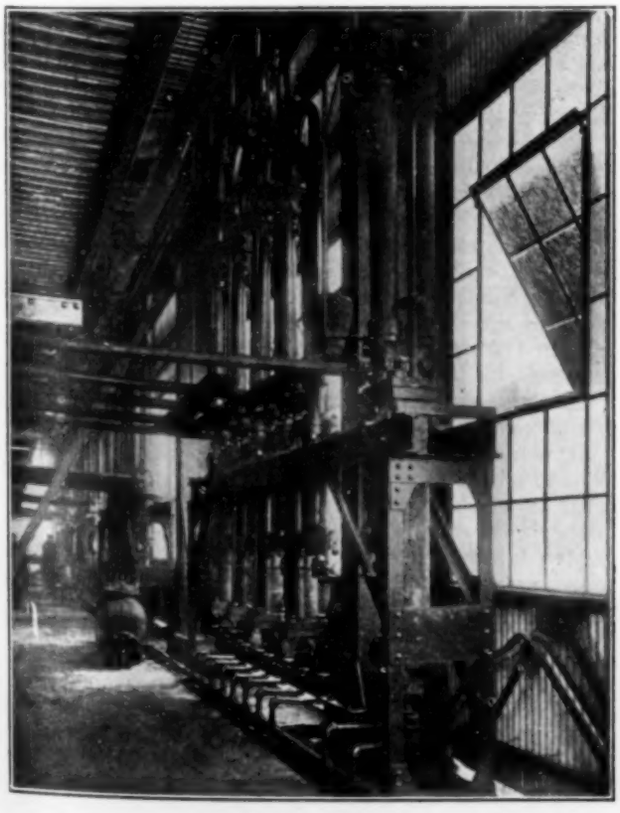
The gases are carried to the condenser through a 3-in. pipe some 12 ft. in length. A receptacle termed the primary separator is connected with the vapor line, in which the more readily condensable liquids are collected. The gases which remain uncondensed at this point pass upward through a 3-in. U-shaped iron pipe into a twin water-cooled condenser consisting of 3-in. copper pipes incased in iron pipes through which water is continually circulated. The liquids which are condensed pass by gravity into what is called the secondary separator. The fixed and uncondensed gases are discharged into a gas header on the upper floor of the furnace building by means of a 1½-in. pipe whenever the pressure on the system exceeds the predetermined pressure.

The primary separator is 8⅝ in. in diameter by 3 ft. 4 in. in height. The secondary separator is 10¾ in. in diameter by 5 ft. 6¾ in. in height. These separators hold as much liquid as will be condensed during a run of the duration permitted by the capacity of the carbon receptacle.

The twin water-cooled condensers are approximately 7 ft. 10 in. in height and have an internal-wall area of approximately 10 sq. ft.

The inefficiency of the condensers, which led to the installation of a large-size condenser and gas scrubber, is shown by the amount of aromatic hydrocarbons in the oil immediately on leaving the condenser and the amount in the same oil after it had been exposed to the air in open barrels, in which it was customary to store it temporarily. It was found that between 30 and 50 per cent of the low-boiling aromatic hydrocarbons formed in the tube had evaporated while the oil was allowed to stand in contact with the air. Some liquid was mechanically carried over by the gases and did not condense in the individual condensers.

The volume of gas formed in the cracking process is



ARRANGEMENT OF CONDENSERS FOR MULTIPLE-TUBE FURNACES

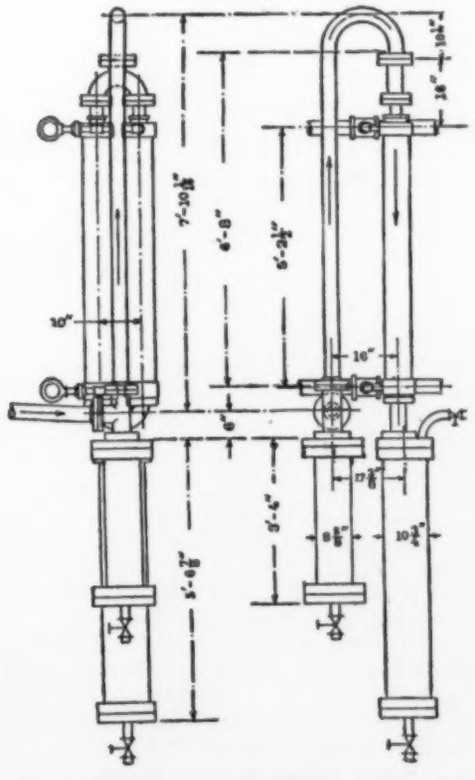


FIG. 4—DETAILS OF CONDENSER CONSTRUCTION

so great that a very considerable percentage of both light and heavy oils is mechanically carried over and does not yield readily to condensation. Traps were placed in the gas line, into which the uncondensed gases were discharged, and analyses have been made for a number of different runs. It was found on distillation from the traps that 50 to 60 per cent boiled over below 175 deg. C., in which cut the benzene content ranged from 5 to 21 per cent and the toluene content from 8 to 25 per cent.

In any new installation for the employment of this process, provision should be made for a condenser of the same type as that used in oil refineries. With the benzone-toluene process, the condensation problem is, however, markedly different from that of the refinery where all the vapors coming from the still are condensable, as in making benzene and toluene considerable volumes of fixed or noncondensable gases are generated. In general a condensing area of approximately 2½ ft. for each barrel of original oil used per day will be found satisfactory if a gas scrubber is operated in connection therewith. This gas scrubber can be modeled after the benzene scrubbing towers in by-product coke-oven plants, or may consist merely of a large tank filled with a heavy oil through which the gases are bubbled. This tank should be so inclosed that the fixed gases can be conducted to a gas holder for the purpose of supplying fuel for the furnaces, if desired. In by-product coke-oven practice the introduction of back pressure by forcing gas through a body of oil would seriously affect the coking products, whereas in the process herein described there is sufficient direct pressure to work against any desired head of oil.

GENERAL DESCRIPTION OF CRACKING SYSTEM IN COMMERCIAL PLANT

The cracking system, both in the benzone-toluene and gasoline processes, is a closed one. Pressure is maintained throughout the entire system while operations are being carried on. The component parts of the system are shown in Fig. 3, in which the various parts are labeled.

The oil is delivered by the pump through the feed line passing under the upper floor, and is carried into the tops of the tubes at a predetermined rate of feed. In the benzone-toluene process the rate of feed is approximately 15 gal. per tube per hour. This rate would be more than doubled in the gasoline process for tubes of the same size. Only a very small quantity of oil is present in the tube in a gaseous form in a given period of time, as a rate of 15 gal. per hour is equivalent to the delivery of only 1 quart of oil per minute. If the oil is preheated, a much higher rate of feed can be attained in both processes.

The oil, upon entering the top of the tube, is spread out over the surface of the basket, which consists of a cast-iron pipe with a perforated top. In the laboratory experiments a basket filled with steel balls was used. These balls were also used in the furnace containing a battery of ten 4½-in. tubes. It was found, however, that the same results could be obtained by dispensing with the obstructing material and using a spreader of the type mentioned.

The pumps are so set as to deliver the oil under a pressure greater than that in the tubes, so that no difficulty is experienced in causing the oil to flow into the tubes regardless of the pressure employed. The hydrocarbon material fed in is flashed or instantaneously transformed into a gaseous condition and passes downward through what is termed the "cracking zone" of the tube proper, where a temperature is maintained higher than that in the gasification zone. It is in this part of the container that the heavy hydrocarbons are broken up under the influence of temperature and pressure and in the presence of hydrogen and fixed hydrocarbon gases. Most of the cracking occurs in this zone, although there may be some cracking immediately below the point of gasification. Although not absolutely necessary, it has been found preferable to effect gasification at a point above the cracking zone.

The condensable gases, which are the desired conversion products, pass out of the tube through the tar neck and enter the vapor line leading to the condenser. The gases which remain uncondensed ascend through the gas line connected with the top of the secondary separator and are discharged through pressure release valves either into the open air or into the gas header. The release valve discharging into the open air is used so that in case of any difficulty arising the pressure can be released in the minimum space of time.

The process, however, is not limited to the use of petroleum products, but can be efficiently operated on liquid hydrocarbon material derived from any source. Solvent naphthas, and light oil distillates from water-gas tars and coal tar have been successfully used. These light oils and solvent naphthas are extremely favorable for use in the process as yields two to three times larger than those obtainable from petroleum products can be had in a single operation. The petroleum oils, howeved, give a wider range of by-products. This fact, together with their greater availability, as well as lower cost, probably render them most suitable for use. Wherever supplies of the distillates from coal or water-gas tar are available in quantity, they are a most prolific source of benzene and toluene. If such distillates were procurable in the open market their use would be highly profitable at a time like the present (1915), when both benzene and toluene are commanding heretofore unheard-of prices.

The great advantage in the use of light-oil distillates from coal and water-gas tars, aside from the greater yields obtainable, is the fact that diminished pressure can be used. Vacuum or atmospheric pressure has been shown to give results as favorable with these oils as higher pressures.

The experiments have clearly indicated that the vapor-phase cracking process is not limited to any particular type of oil, and that an asphaltic oil, a paraffin-base oil, oil having a paraffin and asphaltic base, and certain oils obtainable from the destructive distillation of coal, are all suitable for use in the process.

The combustion chamber in the multiple-tube furnace contains approximately 1100 cu. ft. of space or an average of 110 cu. ft. per tube. This combustion volume seems to be insufficient for the best results under the conditions of operation which have existed during the period covered by this report. It is believed, however, that much better results could be obtained with this volume of furnace per tube if it were to be combined with an efficient outer combustion chamber.

In the operation of the plant a laborer, termed a heater, is employed for each furnace of ten tubes. This man has charge of the 22 burners required to heat a single furnace, and is engaged constantly in the regulation of the burners in order to maintain the required temperature. This regulation of heat is controlled by optical determination of the temperature, as judged by the condition of the tube and brickwork in the interior of the furnace. Pyrometers have also been used, but have given results of varying character.

Pressure in the cracking system is maintained by controlling the discharge of the gases formed by the decomposition of the hydrocarbons fed into the tube. In the operation of the process at the development plant

a laborer is employed for each unit of five tubes in order to regulate the pressure. Regulation is accomplished by opening a valve and permitting the gases to escape into a gas main or header until the pressure in the individual tube has been sufficiently lowered to keep it at the point required.

When as large a quantity of benzene as possible is desired the pressure used was 250 lb. per square inch. When it was desired to obtain more toluene a pressure of 150 lb. was used.

As was stated in the discussion of temperature, carbon difficulties increase when heat is not uniformly regulated. The experiments again indicated the already well-known fact that the percentage of carbon formed increases with temperature.

The presence of carbon in the reaction chamber is a disadvantage from the mechanical side alone. From various references in the appended bibliography it can be discovered that carbon is one of the best catalysts for the formation of benzene and toluene.

It is evident from the development of the process that formation of carbon in the cracking tube is not an obstacle to the operation of the process when control conditions are in proper relationship. Too low a rate of feed at a moderately high temperature will cause higher percentages of carbon to form. Excessive temperatures and pressures will likewise promote excessive carbon formation, but when these factors are in their proper relationship the character of the carbon is such that little or no difficulty is encountered in its removal.

Plain lap-welded tubes have not proven entirely satisfactory. A small number of lap-welded tubes that were calorized (coated with aluminium) by the General Electric Company have been in operation for several weeks. The results to date of writing have been entirely satisfactory, especially as less carbon trouble has been experienced with these tubes than with like tubes not calorized.

Based upon experience extending over a period of seven months, it is recommended that either rolled or cast steel tubes be used in lieu of lap-welded tubes. The walls of the tubes should be not less than 1 in. thick for maximum efficiency in operation.

The benzene-toluene process produces more than enough gas for continual operation of the cracking furnaces. Regardless of the character of oil used, 40 to 50 cu. ft. of fixed gases is generated for each gallon of oil cracked.

Very small amounts of gas are produced in the gasoline process as compared with the benzene-toluene process, consequently either natural gas, oil, or some other form of fuel would have to be employed to heat the cracking furnace.

Up to the time of writing no opportuity has been afforded for the detailed study of that part of the recovered oil distilling above 175 deg. C.

It is difficult to give cost data for a unit plant for either the gasoline or benzene-toluene process. Although several plants are being projected for 1916, only one plant has been constructed during the period for which data have been given. This installation is the one owned and operated by the Aetna company. The conditions under which this plant was erected were such as to make the costs unusually high. Consequently it would not be fair either to the company or to the process to quote such figures. Also their quotation is inadvisable.

The cost of a gasoline plant will be considerably less than that of a benzene-toluene plant, as little or no carbon is formed and elaborate equipment for the removal and reception of this substance is not required; also a gas scrubber and a gas holder would not be needed, as the volume of fixed gases generated in making gasoline is small.

Large-Scale Gasoline Production

Opportunity has not been afforded for testing the gasoline process on a large commercial scale, as is the case of the benzene-toluene process. The inability of the Department of the Interior to accede to the requests made for exclusive rights, or for recoupment of expenses incurred in the development of the gasoline process, has prevented reaching an understanding. At the time of writing licenses have been issued to four refining companies, each of which is about to install small experimental units.

The Aetna Explosives Co. has been most courteous and obliging in extending facilities for conducting gasoline tests in the single-tube furnaces, during such times as the use of the furnaces could be spared for this purpose. Accordingly a considerable number of runs were made in the single tubes with the different oils available. Three oils were used in the experiments, one was a fuel oil from Pennsylvania-West Virginia crude petroleums and the other two were distillate oils, one having a boiling point ranging between 250 deg. and 350 deg. C., and the other between 200 deg. and 300 deg. C.

Experiments were made with a 6-in. by 9-ft. tube and with an 8-in. by 10-ft. tube. The average percentages of gasoline recovered were low, being 18.8 per cent and 21.5 per cent with the 6-in. by 9-ft. tubes using two distillate oils and 19.5 per cent with the 8-in. by 10-ft. tube using distillate oil. An average recovery of 24.3 was obtained with a distillate fuel oil in the 8-in. by 10-ft. tube but the average percentage of recovered oil was lower.

In considering the figures obtained, it must be remembered that efficient condensation was lacking. The work was carried on during intervals when benzene-toluene experiments were being conducted with equipment erected to obtain indications as to benzene-toluene reactions, and not to determine maximum yields. Accordingly the condensing facilities were of the crudest type. The results can be considered only as suggestive of what can be accomplished under proper conditions. Viewed in this light they are of a distinctly favorable character, and justify optimistic belief in the large-scale commercial possibilities of the process.

GASOLINE PROCESS COMPARED WITH BENZENE-TOLUENE PROCESS

In comparison with the benzene-toluene process, the gasoline process is simple in character. This may be more readily perceived by considering the order of hydrocarbon reactions as given below. The relative order is not only based on theory, but is in accordance with the evidence gained as the result of extended series of tests.

The order of the reactions is as follows: heavy petroleum hydrocarbons $\rightleftarrows$ light petroleum hydrocarbons (saturated and unsaturated) $\rightleftarrows$ cymene $\rightleftarrows$ xylene $\rightleftarrows$ toluene $\rightleftarrows$ benzene $\rightleftarrows$ naphthalene, diphenyl, etc., $\rightleftarrows$ anthracene, $\leftrightarrows$ carbon and gas.

The conversion from heavy hydrocarbons into lighter hydrocarbons involves only one step, and is easy of accomplishment, whereas the conversion into the lower boiling aromatic hydrocarbons requires that the heavier hydrocarbon molecules undergo a much more extensive series of changes before the desired products are obtained. This difference will indicate why the mechanical difficulties experienced in the first stages of development of the benzene-toluene process are non-existent so far as the gasoline process is concerned. The lower

temperatures necessary and the greatly decreased quantity of carbon produced eliminate serious trouble from overheating and clogging in gasoline manufacture.

Because of the greater ease with which gasoline can be made the installation used for benzene-toluene production will have double the capacity when used for conversion of heavy oil into gasoline. The duration of the gasoline reaction is less than half that required for the benzene-toluene reaction if the same size and length of tubes be used. It is manifest, therefore, that by introducing twice the volume of oil to be converted, the effect will be the same as decreasing the time factor by one-half.

The installation if used solely for gasoline production can be materially changed in many respects. The expensive carbon receptacles can be done away with, and the height of the furnaces above the ground materially reduced, thus lowering the cost of furnace construction.

The large-scale experiments have fully confirmed the laboratory experiments and established the fact that the conversion into gasoline can be even more satisfactorily accomplished in a tube of greatly enlarged diameter and increased length than in the electrically heated 1½-in. tube. The conditions favorable for gasoline production are shown to be the same in the larger tubes as in the small tube, namely, a temperature of approximately 500 deg. to 575 deg. C. and a pressure of 250 to 300 lb. per square inch.

The gasoline process, therefore, can justly be considered as a success so far as conversion in the large tubes is concerned. The adaptation of the unit to refinery conditions is a matter of mechanical detail involving no inherent difficulties.

Early in September, 1915, the Department of the Interior was advised by the Aetna Explosives Co. that the plants were completed for the production of explosives from benzene and toluene obtained by the process of cracking in the vapor phase. In accordance with the express understanding between the company and the bureau, this necessitated the severance of the co-operative relations existing. This understanding was had to obviate any objection due to the utilization of Government employees in work involving the preparation of explosives.

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Metallurgy of Native Silver Ores of Mexico.—In a paper presented at the second Pan-American Scientific Congress, Washington, D. C., Mr. W. M. BRODIE discusses the treatment of native silver ores occurring in Chihuahua, Mexico. Ores of this type were worked at Batopilas before 1632, by methods of sorting and cobbing together with smelting in crude forms of reverberatory and blast furnaces. At the present time the silver is recovered by concentration, amalgamation, cyanidation and smelting. The enriching of the ore begins in the mine, where pains are taken to separate high and low-grade material.

The high-grade ore is fed by hand to stamps, the fine passing the screen and the coarse remaining in the mortar. The latter is removed and washed by hand, after which it is ready for refining. The stamp discharge which has pased a 30-mesh screen, is treated in amalgamation pans with 0.5 per cent cyanide solution, and as soon as the grinding is completed mercury is added to collect the metallic silver. The pan tailing is discharged to a settler and thence to a Dorr thickener and Pachuca agitator, being treated in the last machine with 0.5 per cent cyanide solution. The amalgam, which may contain from one-third to one-half silver, receives the usual treatment, and the retort silver runs about 950 fine.

Low-grade ore assays from 10 to 20 oz. silver per ton, depending on its proximity to high-grade deposits in the mine, but is usually of 10-oz. grade. This is concentrated on tables of the Bartlett and Wilfley types, the tailings containing about 2 oz. silver per ton. The concentrates are reconcentrated and separated into two grades, one containing 3000 to 7000 oz. per ton and the other from 200 to 400 oz. A third-class concentrate of about 100 oz. may be obtained, and the tailing usually carries between 8 and 9 oz. per ton. The ratio of concentration is about 50:1.

The first-class concentrate is treated in an amalgamating pan with cyanide solution and mercury, and is reduced in value to about 30 oz. per ton. It is then added to the other pan tailings in the Dorr thickener. The second-class concentrate is cyanided by percolation together with the coarse settlings from the settlers in which the pan tailings are washed after amalgamation. The silver leaches slowly but without difficulty.

The silver is precipitated on zinc shavings in the usual manner, and the precipitate is filtered and dried in a cast-iron retort. It is then refined together with the stamp-mill silver and the pan silver in a reverberatory furnace of the Freiberg type. The pan and stamp-mill silver are charged first, and when the contained silica floats on the charge, the cyanide precipitate mixed with about 5 per cent borax glass is added. In this way a fairly fusible slag is made and skimmed. If the bath is kept at the proper temperature there is no great loss of silver by volatilization.

Slags from refining are ground and sifted to recover metallic silver, which is then treated in an amalgamating pan with cyanide solution and mercury in a manner similar to that used for high-grade concentrates. This avoids by-products and cleans up the operation quickly.

Copper

Leaching at Chuquicamata, Chile.—The metallurgical methods employed by the Chile Exploration Company in treating the copper ores at Chuquicamata, Chile, were outlined in detail in this journal May, 1914. Since that time the proposed methods have been put in successful operation, and some data from practice are given by Mr. C. A. ROSE in a paper presented at the second Pan-American Scientific Congress, from which we abstract the following:

The ore is leached in 10,000-ton concrete vats, and the first solution is applied by upward percolation in order to avoid an accumulation of fine ore at the bottom of the vat. This solution is allowed a contact of from thirty-six to forty-eight hours, when it is withdrawn and replaced with solution acting by downward percolation. The following extract from a report sheet will show the cycle of treatment:

LEACHING OPERATION SHEET

Charge No. 41 — Date charged, Oct. 9, 1915
Tank No. 5 — Tonnage..8,212 met. tons

Date Oct.	Solutions Put on Grams per Liter Cu. M.	Copper	Acid	Chlorine	Solutions Drawn off Grams per Liter Cu. M.	Copper	Acid	Chlorine
13	3.300	34.8	68.0	1.9				
17	2,560	21.7	69.5	0.7	2,700	47.8	38.0	4.9
18	2,050	25.0	50.4	0.6	2,320	42.1	52.0	3.0
	3,275	36.4	43.6	2.8	3,312	36.3	48.0	2.1
	3,225	30.7	32.8	2.8	3,312	35.4	43.1	2.5
	3,375	21.6	19.6	2.4	3,275	30.9	32.8	2.6
	3,287	7.9	8.4	1.0	3,300	22.1	19.1	2.3
	Water 600 tons				2,800	11.2	7.8	1.1

A part of the last solution withdrawn in each cycle is removed for complete deposition of copper, after which it is discarded. The solution thus removed compensates for the increase in volume due to the addition

of more water in the last wash than is discharged as moisture in the residue, and also removes continuously certain impurities that otherwise would accumulate in the solution. These impurities consist of sulphates of sodium, potassium and magnesium, which are in no way detrimental to the process. They accumulate until the circulating solution contains about 150 grams per liter of sodium sulphate, 10 grams potassium sulphate and 65 grams magnesium sulphate, after which the discarded solution removes the same quantity at each cycle as is introduced by the ore. Iron sulphate does not accumulate rapidly, amounting to only 3.4 grams per liter after treating forty-five charges of ore. Some nitric acid exists in the ore, due probably to nitrates blown from adjacent nitrate beds. This acid is prevented from accumulating by the discard of solution. Chlorine is removed in the dechloridizing plant, where the solution is passed through tube-mills containing granulated copper. This precipitates cuprous chloride, which is separated by filtration. Various methods of treating this cuprous chloride have been tried—by smelting, electrolysis and cementation. The last process is indicated as the most suitable, due to the need of securing cement copper for the dechloridizing tube-mills. The method of treatment is dissolution in brine and precipitation on scrap iron. The consumption of iron is less than half that usually found in treating copper solutions, since the copper is in the cuprous state and practically no free acid is present.

Magnetite anodes were first used for electrolytic precipitation, but owing to the impossibility of securing these from Europe on acount of the war, duriron has been substituted with success. This material is a silicon-iron alloy, and while not wholly unacted upon by the solutions, from fifteen to twenty times its weight of copper can be deposited before the anode is entirely corroded. Duriron anodes have an advantage over magnetite in their mechanical strength, but a disadvantage in requiring about 15 per cent more electrical energy for the deposition of the same quantity of copper. The purity of Chuquicamata copper is somewhat higher than that derived from American electrolytic refineries; its conductivity is from 100.5 to 101 per cent, Matthiessen's standard.

Metallurgical Methods of the Braden Copper Co.—Two recent publications give interesting data on copper concentrating and smelting at Sewell, Chile, the scene of operations of the Braden Copper Company. In a paper presented before the second Pan-American Scientific Congress, Messrs. R. E. DOUGLASS and B. T. COLLEY, respectively concentrator and smelter superintendent, describe the development of the entire plant at Sewell. Until the advent of flotation, concentration was effected by the usual gravity methods, using Harz jigs, tables and buddles. The recovery of copper in concentrate was not high, and even after an improvement to the original plant it remained low. Minerals Separation flotation process was installed and has resulted in greatly increasing the saving. Originally the froth from the tailing compartments of the machines was retreated in another plant, but this method has been superseded by returning the free-running froth from the last compartments to the head of the same machine. The tailings from Minerals Separation machines are treated by air cells, both rougher and cleaner types.

The reagents used in flotation are Swedish or American pine-tar oil, fuel oil, sulphuric acid and a small amount of kerosene to thin the fuel oil. A part of the pine-tar oil is added at the Hardinge mills and the balance at the head of the flotation machines. A sulphuric acid plant is operated intermittently as needed.

The first smelting plant consisted of agglomerating or sintering apparatus and a small blast furnace. Owing to excessive loss of sulphur in the sintering operation, the large percentage of fine ore and high operating cost the agglomerating process was not a success. In the second smelting plant the concentrates were briquetted and smelted in a blast furnace, since local conditions made the use of the customary reverberatory inadvisable. There was no difficulty in briquetting the concentrates by the addition of clay, but the concentrate was already high in silica and alumina and called for extraneous flux to form a slag. Limestone was scarce and cost $12 per ton. The components of the charge were briquet concentrate, converter slag and limestone. The converter slag was easily fused and the sulphides in the briquets quickly melted and separated themselves from the gangue, leaving in the furnace a difficultly fusible skeleton of silica and alumina. Later the flotation plant began operations and imposed a new set of conditions on the furnaces. The flotation concentrates were very fine and easily fusible, but being excessively wet they blanketed the charge and greatly increased the coke consumption. In order to improve these conditions further experiments in downdraft sintering were initiated and a good product was finally made. Still later experiments showed the feasibility of nodulizing the concentrates, all kinds of the latter being treated. The result was the adoption of nodulizing kilns, advantage being found to lie in long kilns of large diameter. The latest type is 100 ft. long and 9 ft. diameter, The smelting of nodules has proved successful and in accord with usual blast-furnace practice, and the fuel consumption dropped to 8 per cent per ton of charge.

In the company's monthly publication, *Teniente Topics*, the following data are given relative to smelting: The concentrate contains 19 per cent copper, 17 per cent silica, 23 per cent iron, 2 per cent lime, 8 per cent alumina and 28 per cent sulphur. Of 350 tons of this material, recovered from 4000 tons of ore, about 215 tons is nodulized, 50 tons is sintered on grates, and 85 tons is smelted raw. The matta resulting from smelting the mixture of nodulized, sintered and raw concentrates contains about 45 per cent copper, and is converted in Pierce-Smith basic-lined converters.

Lead and Zinc

Preferential Flotation of Galena and Blende.—The Australian *Mining and Engineering Review* gives a description of the separation of galena and blende at the works of the Sulphide Corporation, Broken Hill. In this plant the Minerals Separation machines have been superseded by the Hebbard-Harvey under-drive machines, and the capacity is about 4000 tons per week. The flotation plant handles tailings from the lead mill, where the largest part of the galena is separated. These tailings carry 4.2 per cent lead and 18 per cent zinc. The pulp is first agitated with eucalyptus oil, and the froth carries 57 per cent Pb. The residue assays 3 per cent Pb and 18.5 per cent Zn. In the next flotation treatment oil and acid are used, and the concentrate assays 6 per cent Pb and 47.5 per cent Zn. The final tailing assays 1 per cent Pb and 2 per cent Zn. The process is conducted in the cold and effects the recovery of an additional 15 per cent lead and silver as compared with the process previously in use. Another important factor in this separation is that the new process may permit the fine tabling in the lead mill to be discontinued. Rhodonite forms the principal obstacle to successful tabling, as its specific gravity is between that of galena and blende. Flotation, however, gets rid of rhodonite as well as of other gangue matter, and makes possible an easier separation of the two minerals in subsequent tabling operations.

Iron and Steel

Vacuum-Fused Silicon-Iron.—In a paper in the February issue of the *Bulletin* of the American Institute of Mining Engineers, T. D. YENSEN of the University of Illinois, gives the results of his experiments on vacuum-fused iron containing varying percentages of silicon. The experiments were made in an attempt to improve the iron used in dynamo-electrical machinery. The qualities desired were low hysteresis loss, high electrical resistivity (to reduce eddy-current loss), and high permeability. Previous experiments by the author had shown that pure electrolytic iron, melted and cooled in vacuo, possessed desirable properties in respect to high permeability (about twice that of the best commercial iron) and low hysteresis loss. If the electrical resistivity of this iron, which in the pure state is very low, could be increased without impairing its magnetic properties, an excellent iron for electromagnetic purposes would be produced. Previous experiments by Prof. C. F. Burgess at the University of Wisconsin had shown that when melted in an atmosphere of carbon monoxide at ordinary pressures pure iron absorbed about 0.1 per cent carbon and probably some oxygen as the electric resistance increased more than would be expected from the carbon alone. The iron used in the present experiments was doubly refined electrolytic iron deposited from Swedish charcoal iron according to the methods of Burgess (see this journal, Vol. II, May, 1904). The refined iron had the following composition: carbon, 0.006 to 0.01 per cent; silicon, 0.01 per cent; sulphur, trace; iron (by difference), 99.98 per cent.

The experiments were made in a vacuum furnace modeled after the Arsem type (see this journal, Vol. IV, page 223, June, 1906), and a Geryck pump was used capable of maintaining a pressure of 0.5 mm. of mercury or less with 500 grams of molten iron in the furnace. Previous experiments by the author had shown that carbon and boron when alloyed with this vacuum-fused iron lowered the magnetic quality and they were thus undesirable where high permeability and low hysteresis were needed. The present experiments with silicon gave opposite results and seem to have produced an iron which possesses very remarkable properties highly desirable in iron for electrical machinery. Before being used the iron was crushed, cleaned with hydrochloric acid, water and alcohol and dried by means of ether in vacuo. About 600 grams of this cleaned iron was then placed in a fused magnesia crucible together with the desired portion of the alloying element, covered with a magnesia cover and placed in the vacuum furnace where it was melted under a finishing pressure of 0.5 mm. of mercury. The ingots, after being allowed to cool in the furnace, were heated in an ordinary coke forge and forged into rods about ½ in. (1.25 cm.) by 20 in. (50 cm.) under a steam hammer. No contamination took place in this operation. From these rods the test pieces were prepared; one rod 14 in. (35.5 cm.) long for the magnetic and electrical tests; two test pieces, 2½ in. (6.3 cm.) long, with threaded ends, for mechanical tests; and one small specimen for the metallographic investigation. Magnetic and electrical tests were made and photomicrographs were taken after the following heat treatments:

(*a*) As forged.

(*b*) Annealed at 900 deg. C. Cooled at a rate of 30 deg. per hour.

(*c*) Annealed at 1100 deg. C. Cooled at a rate of 30 deg. per hour.

Mechanical tests were made as forged and after annealing at 970 deg. C. A few specimens were annealed at 1100 deg. C. The annealing was done in vacuo so as to preclude any possible contamination by gases, the vacuum part of the furnace used for this purpose consisting of an "electroquartz" tube with mercury-sealed ends.

The results are summarized as follows:

By means of the vacuum method of melting it is possible to obtain a decidedly purer product than has thus far been obtained in any other manner. Consequently by the use of this method more definite conclusions than have hitherto been possible can be drawn with regard to the effect of silicon upon iron.

Silicon, like boron, has a double effect upon iron. Part of it combines with the iron and remains in solid solution throughout the cooling of the alloy, while a smaller part reduces the iron oxide present.

The tensile strength of the vacuum product follows in general the same law as alloys made under ordinary conditions, but the ductility of the former is much greater, particularly below 2 per cent and above 3 per cent, probably due to the absence of carbon. The maximum tensile strength of 105,000 lb. per square inch (73.5 kg. per square millimeter) occurs with a silicon content of 4.5 per cent.

The limit of forgeability lies between 7 and 8 per cent silicon. A critical range occurs between 2.50 and 2.60 per cent, in which the alloys are exceedingly brittle, in some cases being not even forgeable. The chemical composition of the latter corresponds to a compound of the formula $Fe_{15}Si$.

With regard to the magnetic properties, the vacuum alloys exhibit most remarkable characteristics. The best alloys are obtained with about 0.15 per cent, and 3.40 per cent silicon after annealing at 1100 deg. C. The maximum permeability for both of these alloys is above 50,000, and the hysteresis loss for $B_{max} = 10{,}000$ and 15,000 is about 300 and 1000 ergs per cubic centimeter per cycle respectively. This hysteresis loss is 1/8 and 1/3 of the corresponding loss for commercial silicon steel. The most favorable annealing temperature is in every case 1100 deg. C.

The specific electrical resistance increases about 13 microhms for the first per cent silicon added. For each additional per cent added the increase is about 11 microhms. Consequently the 3.40 per cent alloy mentioned above has a resistance nearly five times that of the 0.15 per cent alloy.

By the vacuum process two silicon alloys have thus been produced that have very valuable characteristics; one low in silicon, not very strong, but extremely ductile, of high permeability, low hysteresis loss, and of low electrical resistance; the other high in silicon, very strong, moderately tough, of high permeability, low hysteresis loss and of high electrical resistance. The properties for these two alloys are summarized in Table I. The first is evidently suitable for use in places where high permeability and low hysteresis loss are the chief requirements, while the second alloy is suitable for electromagnetic machinery, principally transformers, where a low eddy current loss is an additional requirement.

Table I—Properties of the Two Best Iron-Silicon Vacuum Alloys

Silicon Content per Cent	Stress at Yield Point, Lb. per Sq. In.	Ultimate Strength, Lb. per Sq. In.	Elongation, per Cent	Reduction of Area, per Cent	Maximum Permeability	Density for Max. Permeability, Gausses	Hysteresis Loss, Ergs/c.c./Cycle: For B_{max} = 10,000	Hysteresis Loss, Ergs/c.c./Cycle: For B_{max} = 15,000	Spec. Elect. Resistance, Microhms
0.15	18,500	37,000	50	90.0	Above 50,000	6,500	286*	916†	11.99
3.40	58,000	76,500	21	28.5	Above 50,000	6,500	280*	1,025†	68.5

*From data recently obtained with rings these values may be 10 to 20 per cent low.
†From data recently obtained with rings these values may be 5 to 10 per cent high.

Recent Chemical and Metallurgical Patents

Iron and Steel

Regenerative Furnace.—A regenerative furnace for open-hearth steel practice, which uses pulverized coal, forced draft, and may be placed above the open-hearth furnace proper and within the same walls, is patented by JOHN E. BELL of New York City. The arrangement of the regenerator is shown in Fig. 1. Air is blown in through 7 from a blower, and passes through the successive parts of the right-hand generator, *a*, *b*, *c*, and *d*, respectively, when the valve is arranged as in the drawing. At the same time pulverized coal is fed in at 17*a*, in separate combustion chamber 5*a*. The falling coal and preheated air unite and the coal burns forming a producer gas, which passes under 14*a* and up through 3*a* to the hearth of the furnace 2. The ash of the coal falls on grate 15*a* where steam or steam and air is introduced to aid in consuming any unburned

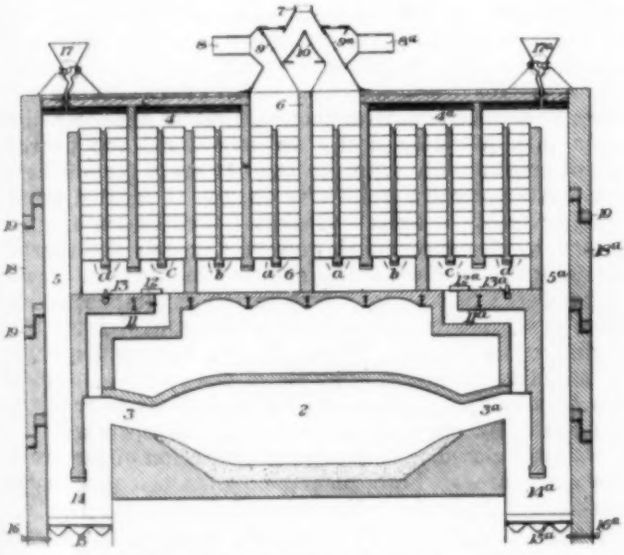


FIG. 1—REGENERATIVE FURNACE

carbon and prevent the formation of clinker. The gases pass out at 3 and up through chamber 5, to second regenerator 4, and thence through 8 to the stacks. When reversed the coal is stopped at 17*a* and is fed in at 17 in the other side.

A secondary combustion may be effected by introducing auxiliary heated air through passages 11, the amount regulated by check damper 12. Steam may be admitted at 13 and 13*a*, to regulate temperature of regenerator or water tubes may be inclosed in the furnace walls to take up some of the heat. This regenerator may also be placed alongside of or below the furnace proper. Straight, smooth passages are made in the regenerator which take 2000 to 4000 lb. of gas per square foot of flue area per hour as compared with 500 lb. average in ordinary practice.

The advantages claimed for this combination are a considerable economy in fuel, a low stack temperature, and efficient combustion with long controllable flame. An advantage is claimed in having the regenerator inclosed as a unit with the furnace and in using blowers which give, on account of the high velocity, a sort of eddy or mixed flow to the gases similar to smoke coming out of a stack, whereby a better heat transfer is made. (1,170,397 Feb. 1, 1916.)

Valve Mechanism for Regenerative Furnaces.—A valve mechanism for shutting off the gas supply and stack draft during the reversing operation is patented by LOUIS N. MCDONALD of Youngstown, Ohio. During the reversing of the gases in the regenerative firing system some gas escapes into the chambers which escapes unconsumed to the stack when the valve is completely reversed. In order to prevent losses of this kind it is proposed to connect two sliding valves in the flues, one to shut off the flow of gas and the other the stack draft during the reversing operation. These are suitably connected to the reversing valve and are operated with this valve. With both the gas inlet flue and the stack flue closed, the gas remaining in the checker work will flow into the furnace during the reversing of the valve. Another advantage claimed is that an increased pressure will accumulate behind the gas flow valve, which will fill the checker chamber quickly when the valve is opened. (1,170,301 Feb. 1, 1916.)

Method of Producing Aluminothermic Mixtures.—In making aluminothermic mixtures in the thermit process it has been customary to add 15 to 20 per cent of constituents additional to the aluminium and oxide in order to temper the reaction and to alter the composition of the resulting metal. In order to make it possible to add more than 20 per cent of additional constituents without lowering the temperature of the reaction too much, and thus reduce the cost of operation, a method is patented by JOHN H. DEPPELER of Jersey City, N. J. (assigned to Goldschmidt Thermit Co.). In this method the additional constituents are placed in a separate container (which will melt when heated to welding temperature) and preheated by the waste gases from the torch used in heating up the sections to be welded. This container when preheated to a red heat is then placed in the aluminothermic mixture in the reaction crucible and melts together with that mixture in the mold in which the welding operation is carried on. (1,168,061, Jan. 11, 1916.)

Manganese

Colloidal Manganese Dioxide.—Colloidal manganese dioxide used as a depolarizer for miniature batteries used in pocket flashlights is patented by CARLETON ELLIS of Montclair, N. J. The process of making this material is as follows: Five parts of glucose are dissolved in twenty parts of water and cooled in ice. Four parts of a 10 per cent solution of caustic soda is added and then 100 parts of a 5 per cent solution of potassium permanganate is added little by little while cooling the mixture and stirring. The mass stiffens after this addition, in a few minutes, to a jelly and on standing this begins to contract and break up into blocks with separation of liquid. This is facilitated by heating. When forming the colloidal manganese around particles of mineral or artificial manganese dioxide, the above operation is carried out in the presence of this material. The depolarizer has the property of compacting to a firm mass which can be handled without breaking. (1,169,943 Feb. 1, 1916.)

Phenol

Retort for High Pressures and Temperatures.—A retort for producing synthetic chemicals "such as phenol, alpha naphthol, toluene, creosote, pyrocatechin, and other carbon compounds of similar nature, alkalis and hydrochloric acid, etc.," where high temperatures and pressures are desired is patented by JOHN R. WATSON of Baltimore, Md. This retort consists of a high-pressure metal tube with contracted ends, having on its outside electric heating resistances insulated from the body of the retort. Through one end of the retort is placed a thermocouple for automatically controlling the temperature through suitable electrical connections with the heating resistances. On the other end, which is the feed and discharge end, is

a special cap which screws on and which has within it a stem with cone-shaped end which fits into the end of the retort. When the temperature rises to a certain point this stem (which is made of a metal with higher coefficient of expansion and lower melting point than the retort), expands and helps to seal the retort. Should the temperature and pressure go too high, this stem would become soft and allow of an escape into the outer portion of the cap, giving warning and preventing an explosion. (1,169,893 Feb. 1, 1916.)

Electric Furnaces

Electric Furnace for Gas Reactions.—An electric furnace for carrying out gas reactions as patented by ALOIS HELFENSTEIN of Vienna, Austria-Hungary, is shown in Fig. 2. This furnace permits of the intimate association of solid, liquid and gaseous material and catalyzers may thus be used and secondary products also obtained. Gases which it is desired shall react are introduced through pipe 1, through electrode 3, entering a molten bath 7 which is contained in the conducting bottom 6, forming the other electrode. Above this bath is a granular resistance or reacting material with which the gases commingle and then pass into chamber 8, where condensing agents are introduced through nozzles 9. They then pass through flues 10 into connecting chamber 11.

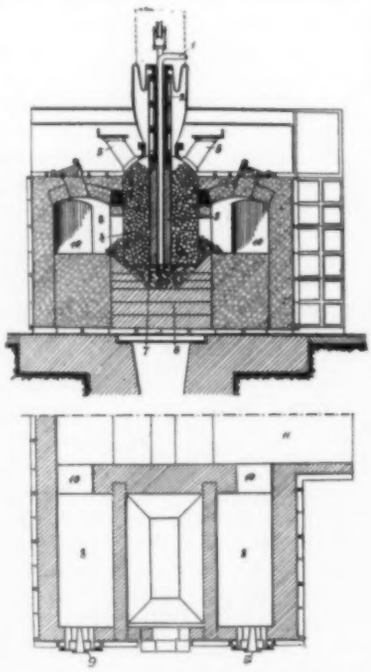


FIG. 2—ELECTRIC GAS REACTION FURNACE

Examples of reactions which may be carried out are given as follows: 1. Acetylene and nitrogen to hydrocyanic acid. Slag bath of clayey earth with floating granular charge of animal coal or charcoal as contact material. 2. Production of carbon tetrachloride by introduction of chlorine into mixture of charcoal and sulphur vapor. Sulphur chloride is first formed, then acted upon by the carbon to form sulphur and carbon tetrachloride. The sulphur may be either absorbed by a silicate slag bath or recovered in the vaporous state. 3. Combining of silicon and nitrogen to form silicon nitride. A quartz bath, over which is a layer of carbon for reducing silica to silicon is used. Nitrogen passed in through electrode. (1,169,817 Feb. 1, 1916.)

Carbon Electrode Production.—A process of making carbon electrodes in which the gases formed are burned and used to heat the furnace is patented by FRANZ NAGELSCHMITZ of Munich, Germany (assigned to Georg Mendheim of Munich, Germany). In this process the coal or coke and tarry binder for making the electrodes are heated in a furnace with a longitudinally extending channel above it for conducting away the gases. The gases pass out of the furnace through a flue into another flue which is also connected to the heating chambers of the furnace surrounding the working chamber. The gases pass from this latter flue back into the heating passages of the furnace where they are mixed with hot air and burned. The furnace produces the heating gas necessary for its operation. The electrodes are prevented from oxidizing by the use of a packing medium of petrol-coke. (1,170,313 Feb. 1, 1916.)

Metallurgical Furnaces

Calcining, Desulphurizing and Agglomerating Ores.—In two patents granted to FRANZ MEYER of Uerdingen, Germany, and by him assigned to Dwight & Lloyd Metallurgical Co., of New York City, the inventor discloses the structure of a furnace for roasting and sintering ores in a continuous operation. The principle of the furnace is similar to that used in the Dwight-Lloyd straight-line sintering machine, viz., forming a layer of ore on a grate, igniting its surface and inducing a down-draft through the mass. In the present instance the furnace consists of an annular grate rotatable about a central mast, the latter being hollow and communicating with the several grate compartments by radial conduits through which the gases of combustion are drawn off. The individual compartments beneath the grate surface are formed by annular plates dipping into a water seal and by cross-partition plates similarly dipping into a water seal. In operation, the charge is fed continuously onto the moving grate from a hopper. At a certain point the charge is ignited when passing under a source of heat. Combustion is sustained by drawing air downward through the charge as the grate revolves. The quantity of air thus drawn is regulated by spring valves in the conduits running from the grate compartments to the central mast, the spring valves, in turn, being actuated by traveling over an annular cam-track. The elevations in the cam-track can be so placed and of such magnitude as to regulate the draft, by allowing the valves to be open wide or practically closed. At the charging section of the grate the cams are so high that the valves are practically closed, and similarly at the point of discharge. The latter operation is effected by a plow scraping the sinter from the grates. (1,162,634 and 1,166,142, Nov. 30 and Dec. 28, 1915.)

A desulphurizing furnace patented by LEWIS B. SKINNER of Denver, Col., is illustrated in Fig. 3. The object of the construction is to secure an improved draft system, whereby the gases will be removed from

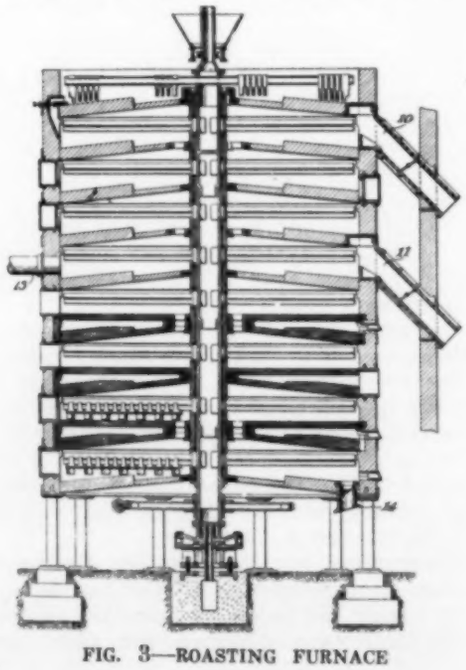


FIG. 3—ROASTING FURNACE

the furnace with as much heat as possible, thus making them more useful for subsequent purposes, as for the manufacture of sulphuric acid. Another object is to construct a furnace that will avoid the generation of excess heat in the middle hearths, thereby injuring the structure. The furnace is of the superposed hearth type, with a central revolving shaft carrying the rabble arms which sweep over the ore on the hearths and cause its movement from hearth to hearth downward through the furnace. As shown in the figure, the three lower hearths are hollow, or of the muffle type. In order to prevent overheating in the middle hearths, special arrangements are made to vary the draft through the furnace. Thus two outlets for gas are shown at 10 and 11, the former at the topmost hearth and the latter opposite a middle hearth. Intakes for air are provided at 13 and 14, the former at a middle hearth and the latter at the bottom. The amount of air admitted and gas leaving the furnace can be regulated by dampers in the outlets and intakes. The result of this arrangement is that there is a uniform temperature throughout the various hearths of the roaster, and the hot gas in the middle zone is removed with all its heat. In a second patent granted to the same inventor means of radiating heat through the furnace walls are provided in the form of steel or iron plates inserted into recesses in the wall of the furnace. Instead of plates, jackets adapted to air or water cooling may be inserted. (1,164,131-2, Dec. 14, 1915.)

Cerium and Alloys

Cerium Used in Alkaline Storage Battery.—A patent has been issued to THOMAS A. EDISON of West Orange, N. J. (assigned to Edison Storage Battery Co.), for an alkaline storage battery in which the positive element is made up of alternate layers of nickel flake and a cerium compound. The material is prepared as follows: A solution of a soluble salt of cerium such as the sulphate is treated with caustic soda and the precipitate is washed and dried and ignited to a white heat in an atmosphere of hydrogen and then cooled down in hydrogen. The product is finely divided and probably consists of an oxide or mixtures of oxides of cerium. For the negative elements of the battery finely divided iron or iron oxides are preferably used. An electrolyte of potassium or sodium hydroxide is used, having added to it a small percentage of lithium hydroxide. (1,167,485, Jan. 11, 1916.)

Gold Alloys.—Alloys intended to be used as substitutes for certain platinum and palladium alloys are patented by KARL G. P. RICHTER of Pforzheim, Germany (assigned to Dr. Richter & Co. of Pforzheim). The alloys are made by substituting a metal of the iron-nickel group, particularly nickel for metals of the palladium group. In this way alloys are obtained which are not much different in cost from the ordinary gold alloys, while the brittleness produced by the nickel is removed by the combination of the nickel with the noble metal. The alloy is malleable and may be used in jewelry manufacture. Instead of pure gold, copper-gold alloys may be used as the starting material. (1,165,448, Dec. 28, 1916.)

Ductile Alloys of High Melting Point.—Alloys for use in electric lamps, firearms or as tools and instruments for various purposes are patented by HANS KAISER of Augsburg, Germany (assigned to Wolfram-Lampen Aktien Gesellschaft of Augsburg, Germany). These alloys are produced by selecting a metal such as tungsten as a base and adding two additional metals before sintering, the first additional metal, such as thorium, consisting of about 1 per cent, and the second additional metal, such as platinum or a metal of the platinum group, being added in very small proportion, i.e., about 1/20 of 1 per cent. The addition of the third metal increases the toughness and ductility and reduces the sintering temperature. (1,167,827, Jan. 11, 1916.)

Counter-Migration of Pulp and Solution in Cyanidation and Acid Leaching

BY BERNARD MAC DONALD

CYANIDATION

Since "all sliming" has been adopted as the most desirable condition, generally speaking, to which an ore should be reduced in order to obtain the best results in cyanide treatment, the efforts of metallurgists have been directed largely to the improvement of the plant apparatus, and of the methods previously used for the agitation of the slime and for the separation of the solution from the leached-out "barren" solids in the treated pulp.

Fig. 1 indicates the means by which these essential objects are automatically secured, and the counter-

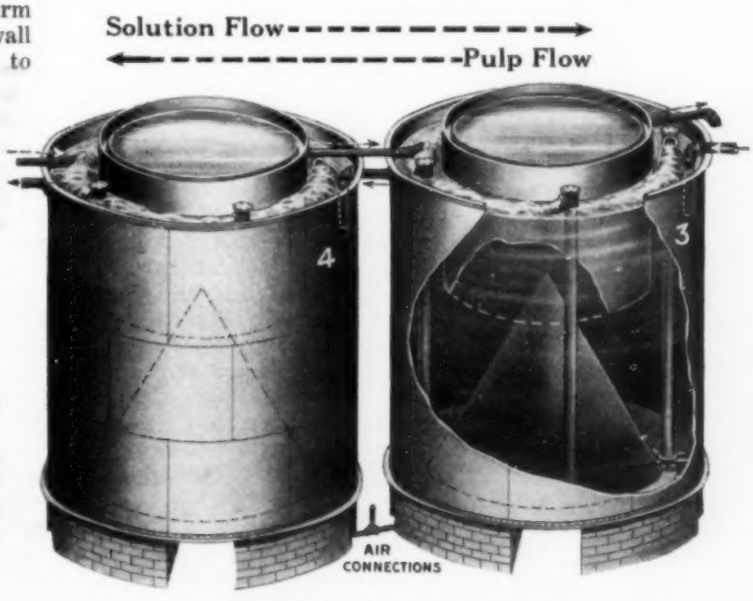


FIG. 1—COUNTER MIGRATION

migration of the solution and solid constituents of the pulp effected in a series of Parral tanks.

The equipment specially instrumental in bringing about these objects consists of a circular diaphragm, water-tight at the sides, open at the top and bottom and supported centrally in the upper portion of the tank. This diaphragm extends vertically down below the pulp level to a certain depth designed to meet conditions, which, for this description, is assumed as 8 ft., and above the pulp level to the height of 2 ft. In this position the diaphragm divides the upper position of the tank into two areas, the annular space between the side of the tank and the diaphragm known as the "agitation circle" and the space inclosed within the diaphragm known as the "separatory area."

The solution and solids in the pulp to be treated may be in any suitable ratio, but for a definite description the usual 2:1 ratio is assumed. In this ratio the pulp contains two parts of solution to one of solids by weight, which gives it a specific gravity of 1.26, or about one and a quarter times the weight of the same volume of water.

In operation the pulp to be treated flows in a continu-

ous stream through a feed pipe which delivers it in the agitation circle two or three feet below the pulp level where it is merged with the pulp in agitation there.

The agitation of the pulp is effected by the mechanical means peculiar to the Parral tank system.

Four transfer pipes, each 6 in. in diameter, are set at quarter points in the tanks, their lower or intake ends reaching within a few inches of the tank's bottom, and their upper or discharge ends emerging about 4 in. above the pulp level. The discharge ends of these pipes are fitted with tees or ells with their discharge openings directed so as to discharge in the same direction around in the agitation circle. Half-inch pipes connecting with the compressed-air main outside the tank are fixed centrally within the transfer-pipes and terminate in a ball-nozzle-valve at a point about 5 in. above their lower ends. Compressed air having a pressure of say 10 per cent higher than the static pressure due to the pulp depth in the tank is introduced through this connection into the transfer pipes which are operated as air lifts. In operation the transfer pipes throw continuous streams of pulp, transferring it from the bottom and delivering it on the top of the tank charge. The spouting force of these streams discharging in the same direction at the surface of the pulp mass in the agitation circle sets up and maintains a rotary flow in the pulp which extends from top to bottom of the tank.

This flow and the continuous withdrawal of the pulp from the bottom of the tank and its redistribution over the surface of the tank charge, gives it the required aeration and keeps its solution and solid constituents in proportionate mixture, a condition which is essential for the effective dissolving out of the metals in the solids.

While the agitation of the pulp is going on in the agitation circle the area within the diaphragm remains absolutely quiet, with the result that the solids settle rapidly out of the contained pulp and sink to the bottom of the tank, there coming within the suction range of the transfer-pipes, they are transferred to the surface where they are carried away in the rotary flow. As the solids settle out of the solution within the diaphragm the clear solution remains in hydrostatic balance with the denser pulp in the agitation circle. This pulp, as above stated, having specific gravity of 1.26, will balance a column of clear solution one and a quarter times its own height. Therefore, the 8-ft. column of pulp outside the diaphragm will raise the clear solution to a height of 10 ft., or 2 ft. above the pulp level in the agitation circle. At the height of 7 ft. 6 in. on the inside of the diaphragm is fixed an annular launder, into which clear solution rising within the diaphragm overflows continuously. From this launder a pipe conducts the clear solution over the top edge of the tank, and delivers it into the agitation circle of the next tank adjoining where it becomes mixed and agitated with the pulp and is again separated from it as above described.

As the solution is thus migrating from tank to tank in each of which it is mixed and agitated with new pulp flowing in the opposite direction, it dissolves out and takes up the metals contained in the solids and thus becomes richer while the solids become poorer as they pass from tank to tank. When the solution is separated from the head tank of the series it is sent to the precipitation room where the values held by it are precipitated and the solution, now barren, is returned to the tail-end tank of the series, where it begins again its migration through the tank series, repeating the same effect above outlined.

The tail end of each series of treatment tanks consists of two tanks used for the settlement of the pulp and decantation of all the solution possible from the pulp before it is discharged to the filter or dump. The equipment of these tanks is similar to the others, but the pulp is received alternately in them, which allows of intermittent settlement, decantation and agitation by which all the solution consistent with flowage is removed from the pulp.

The volume of compressed air consumed in operating the transfer pipes is very small, owing to the fact that the pulp is transferred through them from the bottom to the top of the tank charge under practically hydrostatic balance—a lift of only 4 in. above the pulp level being required. The volume of the streams of pulp transferred may be regulated to any quantity desirable by the valves on the compressed air pipes.

ACID LEACHING

The method of agitation and the counter-migration of the pulp and solution above described is applicable and especially advantageous in the leaching of copper ores by sulphuric acid solution. In this treatment of copper ores the methods are analogous, almost identical with cyanidation, except that the solution being acid requires acid proof apparatus for the agitation of the pulp and the manipulation of the solution.

For copper leaching the Parral tanks and all their equipment are made of wood and are unaffected by the acid solutions. The almost complete separation of the metal-laden solution from the leached-out pulp that is possible to make in Parral tanks by the method described, which obviates the necessity of filtering—the most difficult part of acid leaching—makes this method of treatment worthy of the serious consideration of those engaged in the hydrometallurgy of copper ores.

Los Angeles, Cal.

Paper Thread and Cloth

A Substitute for Cotton

The war has shut off a great many raw materials from Germany which are needed in her industries. This has forced her to invent new materials which suit old purposes but are made from raw materials which can be procured at home. In many ways the ingenuity of the German chemists has manifested itself. One industry which has received attention for this reason is that of paper thread and cloth; it has become important because the cotton supply was practically shut off. A summary of this industry is given in the *Zeitschrift des Vereins Deutscher Ingenieure* Jan. 8, 1916, by W. Heinke. These products have been made in Germany for a number of years without a very general knowledge nor broad application. The paper and textile industries are responsible for their production, and the process is based on Japanese processes in use for 100 years.

The raw materials used are wood cellulose, sawdust, old paper, rags, rope, or waste from the cotton, jute, flax and hemp spinning industries. These are made into paper, and this paper is then cut into strips by machinery and twisted into thread or used untwisted as a substitute for jute thread and cotton thread in linings, carpets, sacks, and other material. The Japanese have for a long time used paper cloth for various purposes, but it remained for Germany to develop machines for cutting and spinning, and create a good-sized industry. At present the cellulose used is mostly from pine and cypress.

A modern strip cutting machine for cutting the paper into strips can cut (according to the makers) 3000 kilograms of paper stock in 10 hr. in strips up to 10 mm. width. Only one workman is needed for this machine. After cutting, the strips are moistened and spun into thread on the spinning machine, which may be of several different types.

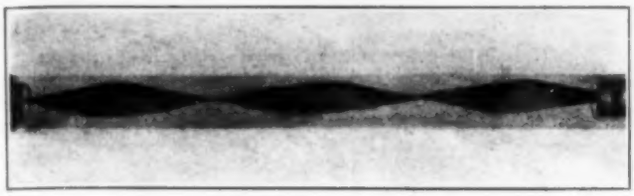


FIG. 1—TWISTING OF DRY PAPER STRIP

FIG. 2—TWISTING OF MOISTENED PAPER STRIP

It is necessary to moisten the strips before spinning, otherwise they will crumple and tear and will not stand the spinning. On the other hand they must not be made too moist, otherwise their strength will be impaired. In Fig. 1 is shown a dry paper strip in the process of turning, which is probably ready to tear. Fig. 2 shows a moistened paper strip spun into a thread. The spinning must not be carried too far or the paper will naturally tear.

The cutting machines are usually of the revolving cylinder type, the paper stock passing between two cylinders. On the upper cylinder the knives are placed, spaced according to the width desired and fitting into grooves on the lower cylinder, the knives being held fast to one edge of the groove. After cutting the paper, it is either wound on spools or is moistened and conducted directly to the spinning machine. For moistening it is run over a cylinder which is moistened by another cylinder touching it and passing through a tank of water below its axis.

The spinning machines have reached quite a high degree of perfection and are described in some detail with illustrations in the original article. They all accomplish the same purpose, but differ only in mechanical details. An improved machine, known as the plate-spinning machine and manufactured by Aktien Gesellschaft Karl Hamel in Schönau, is shown in Fig. 3, and will give some idea as to the extent that this industry is being developed in Germany.

The microscope has come into use in observing the tensions at different stages of the spinning. Practical colors can be produced on the woven fabric by chemical means, and the paper cloth has found considerable use in covering threads of jute, flax, and cotton, giving them a smooth appearance, and covering up loosely spun threads which would make them rough. Unraveling is also prevented, and in the packing of goods with jute this is of considerable value. Metal wire is also covered with this paper material. The paper thread is also woven with textile thread, and the product not only possesses the outward appearance of textile goods, but is also more firm.

FIG. 3—PLATE SPINNING MACHINE

Quite a number of machines have been patented in Germany during the last year for the covering of thread and wire by spinning paper thread over it. Machines have also been devised for covering paper thread with textile thread, and the various uses to which this paper seems to be applicable are evidently unlimited.

By different means it has been tried to make the paper thread waterproof for application in special fabrics. As a result of the war, which produced a shortage of jute and cotton thread, this question is important and a means will probably be found for waterproofing paper threads. For binding twine as well as for sacks the paper thread finds considerable use. The paper thread gives them a certain firmness along with flexibility. The paper thread is not spun to obtain a great firmness as in common textile spinning, but chiefly to give it a round form with the flexibility. Paper threads tested by the author gave strengths on stretching five to six times that of the original paper strip.

As a rule the same twisting frame can be used for weaving paper cloth as for weaving textile cloth. Cloth going by the trade name of "textilose" is a combination of paper and cotton or jute, the cotton or jute usually glued on both sides of the paper. "Textilin" is made by folding and pressing paper strips by a special machine instead of spinning them.

Factories and private experimenters have been quietly working for ten years on the problem, and it is expected that the industry will reach large proportions. From this side of the Atlantic it would seem that the boom of this new industry has been caused by the present shortage of cotton in Germany. Yet necessity is the mother of invention, and many times a new industry has only begun to flourish after the peculiar economic conditions which brought it into existence have ceased to exist.

Development of a Modern Ball-Mill

The use of ball-mills for grinding ore is probably adapted from the cement industry, where such mills were most successfully used for fine grinding of the clinker. Perhaps an earlier use of similar apparatus can be found in the familiar "rattler" of the foundry, which is used to clean castings of various sizes by allowing them to tumble over each other in a revolving cylinder.

The simplicity and efficiency of this type of grinding apparatus has led to its wide adoption in ore treatment, where it has found favor over other forms of grinding apparatus. In its earlier use, in the form commonly known as the tube-mill, flint pebbles were used as the grinding medium and the lining was made of silex blocks. Other forms of lining have been developed, such as the El Oro, in which the pebbles become wedged between iron bars and thus become the lining. The tube-mill is essentially a long cylinder, having a length of from 4 to 4½ times the diameter. Considerable discussion has centered on the requisite length of such mills, many authorities contending that practically all the efficiency of the tube was found in the first few feet from the feed end, and that nothing of consequence in the way of further grinding was accomplished near the discharge end. This has led to the shortening of the tube, thereby reducing the first cost and lessening the power requirement. In at least one case that has come to notice this contention regarding the efficient grinding zone in the long tube-mill seems to have been

established. The tube was 4½ ft. by 18 ft. After being in service for a long time it became leaky, so that pulp discharged at various points along its length. The operator collected samples of the pulp thus discharged, and on making screen analyses of the discharge at various points along the length of the tube he found that practically no efficient grinding was done in the last 14 ft.

Probably the first ball-mills successfully used were made by Krupp of Germany, and were applied in dry crushing. These mills had a screen at the periphery outside of the liners, the latter being so arranged that when the ore was partly ground it would emerge through openings which were somewhat larger than the screen openings that determined the size of final product. That portion of the material that did not pass through the outside screen re-entered the grinding portion of the mill.

The next development of any consequence was Hardinge's conical mill, which, instead of having a cylindrical grinding chamber, is composed of two cones with their bases attached to a short cylinder. One of the cones, at the feed end, is shorter than the one through which the pulp discharges. A high efficiency is claimed for this mill, due to the selective action of the pebbles or balls used for grinding, whereby the larger balls or pebbles remain in the center of the mill and grade to smaller sizes toward the discharge. As the ore particles tend to arrange themselves in similar manner, the larger balls or pebbles work on the larger pieces of ore with intermediate gradations down to the smallest pebbles and smallest particles of ore. Thus it is sought to apply energy as needed in accordance with the size of ore particles.

In this type of mill, however, as with all tube-mills which discharge their products at about the same level with the feed, we have a selective action giving a classified product in which a fine particle of heavy mineral is discharged with a larger piece of light gangue. Since the minerals in an ore are frequently softer than the accompanying gangue, this action may have the effect of grinding mineral finer than is necessary, especially where crushing and grinding are being done for subsequent ore-dressing and not for sliming as in cyanidation.

An earlier type of ball-mill, which in some respects embodied the ideas of the latest types, was known as the Ferraris. It was on the market for a time, but owing to a defect in design which will be pointed out later it did not come into wide use. This mill is illustrated in Fig. 1. It consisted of a revoluble drum divided into two compartments, *A* and *B*, by an annular perforated partition *a*. The larger or crushing compartment *A* was lined with ribbed steel plates and contained forged steel balls varying in size from 3 to 6 in. The smaller or screening compartment *B* was divided into a series of pockets by means of radial partitions extending from a cone *b* that projected back into

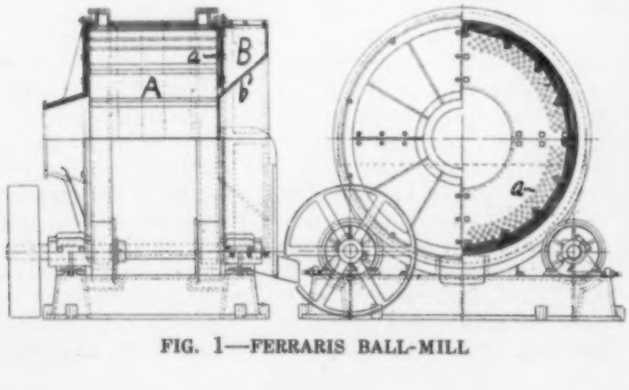


FIG. 1—FERRARIS BALL-MILL

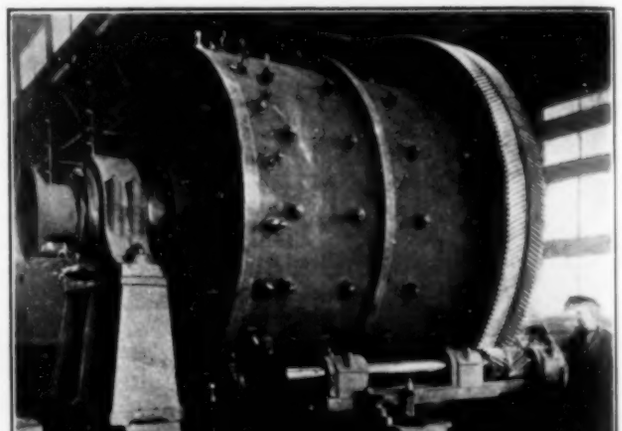


FIG. 2—MARCY BALL-MILL

the crushing compartment. The periphery of the screening compartment was open and surrounded by a screen of the desired mesh. When the ore was ground fine enough to pass the perforations of the annular partition it flowed into the screening compartment and out through the peripheral screen into a housing surrounding the lower part of the compartment. That portion which was not ground fine enough to pass the screen was elevated by the radial partitions in compartment *B* and slid back on the surface of the cone into the crushing compartment *B*.

In the light of later experience the failure of this mill to perform as expected was due to the fact that the oversize was returned at a point where there was little or no chance for further grinding. Had the entire pulp, after passing the annular partition, been screened outside the mill and the oversize returned at the feed end, there would have been effective regrinding; but when it was returned to a point just inside the annular partition there was no opportunity for further grinding, as the oversize immediately short-circuited through the partition and accumulated until the mill was choked. Nevertheless the Ferraris mill may be regarded as the forerunner of the modern short ball-mill, embodying as it did the perforated partition with low discharge and

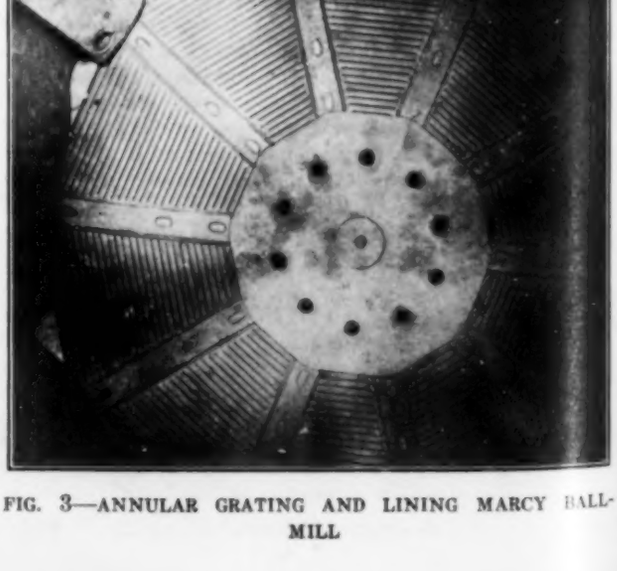


FIG. 3—ANNULAR GRATING AND LINING MARCY BALL-MILL

the radial lifters. But for the failure to recognize the necessity of outside screening and return of oversize at the feed end, we might have had the modern short ball-mill years ago.

In the development of the modern short ball-mill we endeavor to provide a crushing machine in compact form that will take feed up to 3 or 4 in. in diameter and reduce it to, say from 10 to 60-mesh, according to requirements, in one operation, the product being screened or classified outside the mill and the oversize returned with original feed. The grinding medium is steel balls and the lining is of such form as to provide a series of steps or corrugations which lift the charge as the mill revolves. This has the effect of causing the ore and balls to cascade, the former being crushed by impact of the latter. Early experience with such mills showed that they were efficient grinders, but when used with trunnion or overflow discharge on practically the same level as the feed they were subject to the criticism previously mentioned, viz., that the heavier mineral remained in the mill longer than was necessary and was consequently ground too fine. It was to obviate this condition and to produce what might be called an unclassified or non-selective product, that brought about the next important development in ball-milling, viz., discharge at a lower level than that of the feed.

One of the recent mills of this type is known as the Marcy, manufactured by the Mine & Smelter Supply Co., Denver, Colo. As shown in Fig. 2 it consists of a cylinder of greater diameter than length, say 8 ft. by 6 ft. The interior is divided into two compartments by an annular grating of manganese steel, which is well illustrated in Fig. 3. This view also shows the nature of the ribbed lining of the grinding compartment, composed of sectors bolted in place. In the discharge compartment, that is between the grating and the discharge end of the tube, there is a series of pockets formed by radial lifters corresponding to the sectors of the grating, much the same as in the Ferraris mill. The grating has linear openings ⅛ in. wide or less, increasing in width toward the discharge compartment.

The feed end of the mill is fitted with scoop feeders which deliver the ore to the grinding compartment. When the ore is crushed fine enough to pass the grating it flows into the discharge compartment where it is lifted by the radial bars and discharged through the trunnion. In this respect the Marcy mill differs radically from the Ferraris, for the entire pulp is removed from the mill for screening or classification, and the oversize is returned with original feed. Due to the ease with which ground particles pass through the grating, and the rapidity with which they are removed by the lifters, the level of discharge from the grinding compartment is much lower than that of the feed, and as a consequence mineral and quartz particles are removed from the grinding zone with equal facility, and almost as soon as they are ground. This obviates the unnecessarily fine grinding which occurs in a mill with trunnion discharge on about the same level as the feed, wherein the particles have to rise to a high level in order to flow out.

Mills of this type are now being constructed that will take feed as coarse as 4 in. in diameter and deliver a product of 40 or 50 mesh. This makes it possible to eliminate some of the machines heretofore considered necessary in stage crushing in order to reduce ore fine enough for concentration. The best efficiency has been obtained with about 40 per cent moisture in the pulp. The 8 ft. diameter by 6 ft. long mill has a capacity of 1000 tons per twenty-four hours, grinding to 10-mesh; 750 tons to 20-mesh; 350 to 400 tons to 60-mesh. These capacities have been shown on Arizona copper ores. The power requirement is from 200 to 225 hp., and the ball load from 9 to 10 tons. The balls range in size from 5 in. diameter, weighing 20 lb., to 2½ in. in diameter. The Inspiration Consolidated Copper Co. has installed forty of these mills at Miami, Ariz., each having a capacity of from 350 to 400 tons per day, taking crusher feed as coarse as 2½ to 3 in. and delivering a product that will pass a 48-mesh screen. These mills are in closed circuit with classifiers which deliver the oversize back to the feed end. The cost of crushing, including power, oil, maintenance, etc., is stated to be less than 15 cents per ton, and it is hoped eventually to reduce this to 10 cents per ton. Metal consumption of balls on copper ore amounts to about 0.6 to 1 lb. per ton, while the lining consumption is about one-tenth of this amount.

The simplicity of the modern ball-mill, compared with the Huntington, Chilean and other grinding machines, seems to warrant the belief that it is destined to replace many other forms of mills. It is practically fool-proof and the horsepower required is less than for the machines mentioned, considering mesh-tons crushed. The ball-mill is rapidly coming into use for concentration, cyanidation, flotation and amalgamation, in fact, for all processes in which wet crushing and grinding are used, excepting, of course, where coarse concentration by jigging is desirable.

The Present Situation in Graphite Crucibles

The crucible manufacturers have been put to sore straits for the past eighteen months in the securing of their raw materials.

First came the embargo on Ceylon plumbago. This was lifted after a few months, but the market was left in a depleted condition. The natural result was a tremendous advance in price.

Next came the exhaustion of the foreign clay which is used in crucible making as a binder. As far back as crucible history in this country goes the clay used has come from the little Principality of Klingenburg in the Black Forest of Southern Germany, where, so the story goes, the entire government expenses are paid out of the export duties collected from the clays shipped out. This Klingenburg clay has for years past been the only clay which the crucible makers seemed to think could be satisfactorily used. No shipments of this clay have been made since the beginning of 1915.

Some makers have husbanded the enormous supplies of the foreign clay which they had on hand when hostilities started. This husbanding the stock of the now almost priceless raw material has been done by partially substituting clays from various parts of the United States and mixing them with the Klingenburg clay.

The tests and trials made by the crucible makers during the past twelve months have been almost endless. When it is taken into consideration that it takes from six to ten weeks to prepare a graphite crucible for service in the foundry, some idea can be formed of what the crucible maker has to contend with. Added to this delay and before he can even start on these goods that will not be marketable for two months to come, the chemical laboratory tests and trials must be made. These have run into the thousands. Then must come the practical tests in a small way in the foundry; for the crucible maker would stare bankruptcy in the face if he continued making up hundreds of thousands of dollars worth of goods out of Ceylon plumbago, costing from 17½ to 25 cents per pound, only to find at the end of two or three months that they might not be of service to the user.

The bright side, however, to all that is that in many cases the crucibles made with American clays have stood a surprisingly long time in the fires. In one case there is a report on a No. 300, which ran forty heats on manganese bronze, and dozens of cases as high as thirty-eight and forty heats on No. 100's melting car box metal. The chief trouble now seems to be some lack in uniformity of the products secured. Crucibles made by the same potter out of similar materials, at the same time, and burnt in the same kiln, when run by one melter on the same grade of metals are liable to behave so differently from each other that it is a shock to both user and maker.

All this will in time be rectified. As soon as the manufacturers have become more familiar with the mixing and blending of our native clays, they will no doubt be able to produce in time a crucible as satisfactory as or superior to those manufactured heretofore from foreign materials. The user, however, must use more care in handling the American clay crucibles.

It is imperative that these crucibles are thoroughly dry and warm before going into the fire, and that they are heated up *very slowly* on the initial heat.

Some users make a little fire with charcoal inside the crucible, and others put hot ashes in, before placing the pot in the fire, so that the crucible is hot when it goes into the fire for the first heat. There are certain advantages in heating the crucible first from the inside rather than the outside.

Great care must be taken in the matter of wedging, as American clays have not the same tensile strength when hot, as foreign clay.

The advance in prices of crucibles is due to the unusually high price of Ceylon plumbago just at present, but as soon as the war insurances are a thing of the past plumbago will be at a normal figure once more, and crucibles will again be marketed at as low prices or lower ones than they have been for many years past.

A New Electrolytic Oxygen and Hydrogen Installation in a Shipbuilding Plant

At the present time most large users of oxygen for commercial purposes are purchasing it from the manufacturers, having it shipped to them in cylinders containing 200 cubic feet at 1800 lb. pressure. As this entails freight expenses and handling at point of consumption, various large users of oxygen for welding and cutting purposes have installed or are installing their own generating apparatus at their plants.

A new electrolytic oxygen and hydrogen plant just finished and put into operation by the National Ox-Hydric Co. of Chicago at the works of the Fore River Shipbuilding Corporation, Quincy, Mass., is complete in every detail, self-contained, and is run entirely automatically, requiring only the attention of one man to a shift, the plant being run continuously by three men in three eight-hour shifts.

The plant consists of a 75-horsepower Bessemer crude-oil engine, belt-connected to a 45-kilowatt direct-current generator; one of the National Ox-Hydric Co.'s electrolyzers, as shown in the adjoining illustration, guarantees to produce 3500 cubic feet of oxygen per 24 hours and twice that amount of hydrogen; suitable gasometers, compressors, motors and switchboards for control.

The oxygen and hydrogen, after being produced from the electrolyzer, passes into steel gasometers of 2000 cubic feet capacity each. From there they pass through a suction line into suitable compressors, which boost the pressure in the pipe lines between the gasometers and point of consumption to the amount required at the blowpipes. Between compressors and blowpipes or operating stations, are suitable concussion tanks to take the pulsation of the compressors off the pipe lines.

The plant at the works of the Fore River Shipbuilding Corporation is also equipped with high-pressure compressors for the purpose of compressing oxygen and hydrogen into cylinders where it is not advantageous to run pipe lines, such as on board ships and other extreme points of the company's shipbuilding yards. The erection of this plant was begun on December 15, 1915, and entirely completed by February 1, 1916. It is installed in a building of pressed sheet steel 24 x 40 feet.

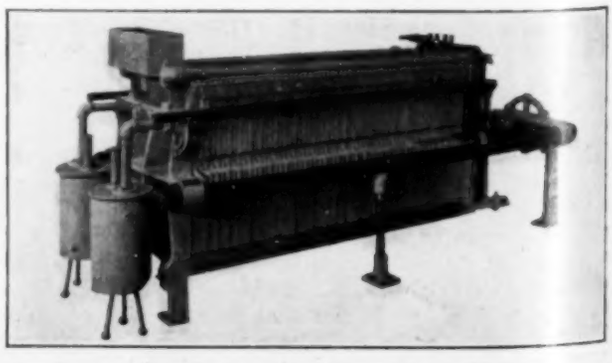
The National electrolyzer is of the improved filter-press type. The present perfected machine is the result of years of study and experiment on the part of expert gas engineers, whose experience and knowledge are based upon extended and exhaustive research and whose work has made it possible for the company to produce a simple and inexpensive method for the production of oxygen and hydrogen gases at a low initial cost.

Fundamentally, the National filter-press type of electrolyzer consists mainly of a number of decomposition chambers connected in series. These chambers are formed by clamping together a series of cast-iron electrodes so recessed and grooved that each plate forms, with its neighbor, a chamber which holds the electrolyte, and in which the generation of the gases takes place.

The electrodes are carefully insulated one from the other by means of patented rubber-bound asbestos diaphragms. The electrodes and diaphragms are arranged alternately and are supported by the insulated frame of the filter press. The required number of electrodes and diaphragms with the corresponding end plates are then pressed tightly together by means of a heavy screw standard, thus making the whole equipment form a hermetically sealed tank of the filter-press type, the diaphragms serving both as an insulation and gasket, and serve to form the sides of the cells, preventing any mixture of the two gases generated. The fact that the electrodes are thus separated by the diaphragms causes one side of the plate to act as the anode of the chamber and the other side as the cathode of the adjacent chamber.

The electrodes are composed of a special alloy, and are heavily coated with nickel, which makes them neutral to oxygen and alkali (from the potash) and prevents the formation of deposits or the oxidization of the electrodes themselves.

The number of chambers required is, of course, dependent upon the production of gases required, as well as the voltage of the electric current. The elec-



FILTER PRESS ELECTROLYZER FOR THE PRODUCTION OF OXYGEN AND HYDROGEN

trolyzers of the National Ox-Hydric Co. are designed for any standard direct current circuit, or, with the use of a motor-generator set, for any of the standard alternating current circuits, thus doing away with the inefficient low voltage, high amperage necessary with the individual-cell type installation. Furthermore, these electrolyzers occupy about one-fifth the floor space, and in many instances less than one-fifth of the floor space, required by the individual cell type.

By the design of electrode the anode and cathode are brought close together, so as to reduce to a minimum the electric resistance, while at the same time the hydrogen gas is effectually kept separate from the oxygen gas without preventing the proper passage of the electrolytic solution between the anode and the cathode.

The electrodes themselves are made with corrugated surfaces, increasing the active electrode surface and forming a large number of very small vertical channels through which the gases rise freely to the upper part of the plates. At the top of each electrode and hermetically sealed together are substantial chambers in which the gases are separated from the electrolyte. From these chambers the gases pass off in a dry state into ducts extending through each plate, these ducts forming continuous conduits, owing to the manner in which the plates are assembled. The gases pass through these conduits into their respective receivers or storage tanks. One of the main features of the design is the way in which the conduits are kept free from electrolyte; this is accomplished by one of the most practical devices known to the gas industry, which device is cast integral with each plate, thereby eliminating any possibility of a short circuit even should the conduits become filled with the solution.

The electrolyte is a 21 per cent solution of pure caustic potash in distilled water. After the electrolyzers are once filled with this solution, distilled water is added from time to time to take the place of the water decomposed; the potash lasts many months. The distilled water is fed to the electrolyzer by an automatic device which maintains a constant level of the electrolyte throughout the machine.

Under normal load conditions, the voltage required per cell is two volts or less. Therefore, to operate on a 110-volt circuit an electrolyzer containing 55 cells is necessary; and on the same basis, 110 cells are necessary for a 220-volt circuit.

The positive pole of the direct-current dynamo is connected with the first electrode in the series, and the negative pole is connected to the last electrode of the series.

The apparatus is provided with one collector for hydrogen and one for oxygen, whereas, the individual-cell type system must have a separate draw-off, or collector, for each cell in use, which necessitates more labor and a considerable increase in upkeep.

Insulation difficulties have been eliminated which prohibit short-circuits and groundings and make the cost of maintenance very small, the labor operating cost being practically negligible.

Assuming continuous operation and normal load conditions as specified by the company, the electrolyzers yield 4 cu. ft. of oxygen and 8 cu. ft. of hydrogen at atmospheric pressure per kilowatt hour of power consumed when the plant is operated at a temperature of 68 degrees F.

The gases produced are of very high purity. The oxygen is of 99.5 per cent purity. The electrolyzer will stand an overload of 50 per cent without any ill effects. This feature of being able to considerably overload the plant and generating a proportionally greater amount of gas is of great advantage.

The operator of one of these electrolyzers should in all cases make a chemical analysis at regular periods of the oxygen and hydrogen gases produced, testing their purity. Other than that his only duty is to maintain a proper water column level of the electrolytic solution.

The water of which the electrolyte is formed has to be distilled in the large commercial plants by means of a properly installed still, but in the smaller individual plants the purchase of distilled water in quantites sufficient to successfully operate the plant is advocated.

The electrodes are practically indestructible. The asbestos diaphragms are very durable, and being neutral to the elements with which they come in contact, have a life fully equal to that of the electrodes. All other parts of the equipment are practically not subject to any wear and tear.

Industrial Notes

The Benzol Products Company, Marcus Hook, Pa., will erect a research laboratory and make other additions to its plant representing an expenditure of $45,000.

The American Coal Products Company, it is officially announced, has decided to unite its name with that of the Barrett Manufacturing Company and the new name will be the Barrett Company. The new company will have the same amount of stock as the American Coal Products Co., which concern was the parent organization of the Barrett Manufacturing Co. and owned its stock.

The International Acheson Graphite Company of Niagara Falls, N. Y., has changed its name, and hereafter will be known as Acheson Graphite Company. It will be noted that the word "International" has been dropped and that the company name now begins with the name of the noted inventor of the process for making graphite artificially in the electric furnace. The change was brought about through the conception that the word "International" had no significance in the company's business and only served to conceal the identity of the company when indexes and other references were examined for the name and address.

The Stupakoff Laboratories, Pittsburgh, Pa., are erecting new laboratories on Hamilton Avenue, and during the erection they are temporarily located at 6364 Frankstown Avenue.

New Lining for Combustion Boats.—The Scientific Materials Company, Pittsburgh, Pa., has placed on the market a new material known as sinderite for lining combustion boats for direct combustion of carbon in steel analysis. The material was developed by the company's research department and is stated to be free from carbon and not to absorb CO_2 from the atmosphere, while possessing other valuable properties which make it a protection to platinum and the combustion tubes.

The Bausch and Lomb Optical Co. has issued a catalog describing its optical instruments for inspection and testing of materials. This includes microscopes and photomicrographic outfits for the examination of ores, metals, rocks, concrete, wood, leather, fabrics, paints, varnishes, oils, dyes, inks, drugs, chemicals, and foodstuffs.

The Chain Belt Company, Milwaukee, Wis., has issued a supplement to their general catalog No. 56. The supplement contains revisions of the general catalog both pertaining to prices and dimensions.

Annealing Cast Bronze.—A study has been completed by the Bureau of Standards, of the annealing of bronze; zinc bronze (copper 88, tin 10, zinc 2) as a type and the results published in Technologic Paper No. 80 which may be obtained without charge from the Bureau of Standards, Washington, D. C. The title of the publication is "Microstructural Changes Accompanying the Annealing of Cast Bronze."

Safety-First Exposition.—A safety-first exposition by government bureaus was held at the New National Museum in Washington, Feb. 21 to 26. Twenty-six bureaus participated in the exposition and apparatus in use by the federal government was demonstrated by experts.

Experiments in Use of Niter Cake.—In the search for a substitute for sulphuric acid, several mills in Yorkshire, England, have carried out experiments in use of niter cake, according to Commerce Reports. The experiments were made in connection with the extraction of grease from suds, for the refining of grease, and other purposes. The chief difficulties are those of handling, drawing of the acid liquid in storage and handling, and difficulty in transportation. The best method is said to be to dissolve the cake in hot water by the aid of steam and to use this solution hot.

Chemical Engineering at University of Michigan.—A special bulletin has been issued by the University of Michigan describing the chemical engineering course and graduate fellowships in gas engineering metallurgy, paint and varnish manufacture, and pulp and paper manufacture. The chemical engineering department, since its foundation in 1898, has been an integral part of the College of Engineering.

Pittsburgh Section American Electrochemical Society.—The regular meeting of this section was held on Jan. 14, Prof. S. L. Goodale spoke on "Some Observations on the Heat Treatment of Steel," illustrated by a projecting microscope using actual etched samples. C. G. Schluederberg was elected chairman and H. C. Ray, secretary-treasurer for the coming year.

The Montana Section of the American Institute of Mining Engineers held its annual meeting and banquet on Feb. 14, at the Silver Bow Club, Butte, Mont. The following officers were elected: Chairman, J. L. Bruce; vice-chairman, W. C. Siderfin; secretary-treasurer, M. H. Gidel; executive committee: N. W. Braly and W. T. Burns. The speakers were Prof. D. C. Bard, who talked on oil prospecting, and Frederick Laist, who talked on zinc metallurgy as practised at Anaconda.

Cornell's Chemical Department Burned.—Morse Hall, seat of the chemistry department of Cornell University at Ithaca, N. Y., was destroyed by fire on Feb. 13. Much valuable apparatus and chemicals were consumed and the loss is estimated at $300,000. The main building was erected in 1890 and it was twice enlarged, Andrew Carnegie giving $60,000 for a recent addition. Several hundred students saved books from the library on the first floor, and the records of the department. Insurance to the value of $200,000 was carried.

Rope-Operated Controllers for Small Cranes and Hoists.—A new reversible drum-type controller designed for overhead mounting, with rope operation is being introduced by the Cutler-Hammer Mfg. Co., Milwaukee, Wis. These controllers are designed for installation indoors for intermittent speed rgulating duty, such as in crane and hoist service. Two types are made, one giving 50 per cent speed reduction under half full load current and the other 90 per cent under light load conditions.

Compound for Removing Scale.—A substitute for sulphuric acid for removing scale from iron, steel, brass, copper, etc., which is finding increasing use at present on account of the high cost of acid is manufactured by the Research Mfg. Co., Oak Lane Station, Philadelphia, Pa. Special progress is being made in the following trades: rods, flats and tubes to be cold drawn; sheets to be tinned or galvanized, brass and copper shells, some grades of castings and forgings. It is adapted for the removal of scale from any metal whether for pickle finish, cold drawing, tinning, galvanizing or enameling. The compound, which is known as Edis compound, is shipped in dry cakes and can be handled readily. It is dissolved in water and heated to 180 deg. Fahr. for use. The vapor is claimed to be non-irritable and not injurious to health.

Personal

Dr. **John A. Brashear,** past president of the American Society of Mechanical Engineers, will be the guest of honor at a banquet given by the Engineers' Society of Milwaukee, Wis., on March 21.

Mr. **W. T. Burns** has been promoted to the position of superintendent of electrolytic refineries for the Anaconda Copper Mining Co. at Great Falls, Mont., and will have charge of both the copper and zinc electrolytic plants. **Mr. E. E. Brownson,** formerly chief chemist, has been promoted to be assistant superintendent of the electrolytic copper refinery.

Mr. **Herman A. Holz,** who has been connected with the Scientific Materials Co. of Pittsburgh for the past five years, has opened offices and showroom in the Hudson Terminal Building, 50 Church Street, New York City. Mr. Holz will deal in precision instruments of high quality for industrial, scientific and military purposes, and will make a specialty of metallurgical research and testing apparatus, pyrometers and hydrostatic recording instruments for pressure, vacuum, volume and velocity of air and gas currents in industrial plants.

Mr. **Woolsey McA. Johnson** is making a professional trip to Kansas and Oklahoma and expects to return in about two months.

Mr. **John G. Kirchen,** general manager for the Tonopah Extension Mining Co., has been elected president of the Nevada Mine Operators' Association.

Mr. **David H. Ladd** of Houghton, Mich., formerly metallurgist of the Wallaroo smelter, Australia, has been appointed general manager of the Sandusky Foundry, Sandusky, Ohio.

Messrs. **Dorsey A. Lyon** and **O. C. Ralston** of the Salt Lake office of the U. S. Bureau of Mines, are making a field trip through the central West investigating the general subject of flotation. They held a conference with other metallurgists at Lawrence, Kan., with a view to arranging co-operative work on flotation experiments and research.

Mr. **Wm. H. Nichols, Jr.,** has been elected president of the General Chemical Company, succeeding Sanford H. Steele, who retired to become general counsel of the company.

Mr. **H. O. Swoboda** has been engaged as consulting engineer by the Humphrey Company of Kalamazoo, Mich., to design a line of electric water heaters.

Messrs. **Theodore S. Tenney** and **Arthur K. Ohmes** will continue in business as consulting engineers for heating, ventilating and power plant work at 101 Park Ave., New York, under the name of Tenney and Ohmes. Mr. Werner Nygren has withdrawn from the company and will practice independently at the same address.

Dr. **Ludwig A. Thiele** announces his establishment as an independent consulting chemical engineer with special knowledge of the design and construction of acid and fertilizer plants. His office will be in the Hartman Building, Columbus, Ohio.